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[NATURE.]

PROF. KIRCHHOFF.

GEHEIMRATH GUSTAV ROBERT KIRCHHOFF was born at Konigsberg on the 12th of March, 1824. He commenced his professorial career at Berlin University as Privat Docent; became Extraordinary Professor in Breslau from 1850 to 1854, thereafter till 1874 Professor of Physics in Heidelberg, whence he was finally transferred (in a somewhat similar capacity) to Berlin. His health was seriously and permanently affected by an accident which befell him in Heidelberg many years ago, and he had been unable to lecture for some time before his death.

It is not easy, in a brief notice, to give an adequate idea of Kirchhoff's numerous and important contributions to physical science. Fortunately all his writings are easily accessible. Five years ago his collected papers ("Gesammelte Abhandlungen" von G. Kirchhoff, Leipzig, 1882) were published in a single volume. His lectures on dynamics ("Vorlesungen über Mathematische Physik," Leipzig, 1876) have reached at least a third edition; and his greatest work ("Untersuchungen über das Sonnenspectrum," Berlin, 1862) was, almost immediately after its appearance, republished in an English translation (London, Macmillan). To these he has added, so far as we can discover, only three or four more recent papers; among which are, however, the following, published in the *Berlin Abhandlungen:*

"Uber die Formänderung die ein Fester Elastischer Körper Erfährt, wenn er Magnetisch oder Dielectrisch Polarisirt Wird." (1884.)

A subsequent paper gives applications of the results. (1884.)

Additions to his paper (presently to be mentioned) on the "Distribution of Electricity on two Influencing Spheres." (1885.)

While there are nowadays hundreds of men thoroughly qualified to work out, to its details, a problem already couched in symbols, there are but few who have the gift of putting an entirely new physical question into such a form. The names of Stokes, Thomson, and Clerk-Maxwell will at once occur to British readers as instances of men possessing such power in a marked degree. Kirchhoff had, in this respect, no superior in Germany, except his life-long friend and colleague v. Helmholtz.

His first published paper, "On Electric Conduction in a Thin Plate, and Specially in a Circular One" (Pogg. Ann. 1845), gives an instance. The extremely elegant results he obtained are now well known, and have of course (once the start was given, or the keynote struck) been widely extended from the point of view of the pure mathematicians. The simpler results of this investigation, it must be mentioned, were fully verified by the author's experimental tracing of the equipotential lines, and by his measurements of their differences of potential. A remark appended to this paper contains two simple but important theorems which enable us to solve, by a perfectly definite process, any problem concerning the distribution of currents in a network of wires. This application forms the subject of a paper of date 1847.

Kirchhoff published subsequently several very valuable papers on electrical questions, among which may be noted those on conduction in curved sheets, on Ohm's law, on the distribution of electricity on two influencing spheres, on the discharge of the Leyden jar, on the motion of electricity in submarine cables, etc. Among these is a short, but important, paper on the "Determination of the Constant on which Depends the Intensity of Induced Currents (Pogg. 1849). This involves the absolute measurement of electric resistance in a definite wire. Kirchhoff was also the inventor of a valuable addition to the Wheatstone bridge. To the above class of papers may be added two elaborate memoirs on Induced Magnetism (Crelle, 1853; Pogg. Ergänzungsband, 1870).

Another series of valuable investigations deals with the equilibrium and motion of elastic solids, especially in the form of plates and of rods. The British reader will find part of the substance of these papers reproduced in Thomson & Tait's "Natural Philosophy." There are among them careful experimental determinations of the value of Poisson's ratio (that of the lateral contraction to the axial extension of a rod under traction) for different substances. These results fully bear out the conclusions of Stokes, who was the first to point out the fallacy involved in the statement that the ratio in question is *necessarily* 1 to 4.

Kirchhoff's "Lectures on Dynamics" are pretty well known in this country, so that we need not describe them in detail. Like the majority of his separate papers, they are somewhat tough reading, but the labor of following them is certainly recompensed. They form rather a collection of short treatises on special branches of the subject than a systematic digest of it. One of the most noteworthy features of the earlier chapters is the mode in which dynamical principles (*e. g.*, the Laws of Motion) are introduced. While recognizing the great simplification in processes and in verbal expression which is made possible by the use of the term Force, Kirchhoff altogether objects to the introduction of the notion of *cause*, as a step leading only to confusion and obscurity in many fundamental questions. In fact, he roundly asserts that the introduction of systems of Forces renders it impossible to give a complete definition of Force. And this, he says, depends on the result of experience that in natural motions the separate forces are always more easily specified than is their resultant. He prefers to speak of the motions which are observed to take place, and by the help of these (with the fundamental conceptions of Time, Space, and Matter) to form the general dynamical equations. Once these are obtained, their application may be much facilitated by the introduction of the *name* Force; and we may thus express in simple terms what it would otherwise be difficult to formulate in words. So long as the motion of a single particle of matter only is concerned, we can, from proper data, investigate its velocity and its acceleration, as directed quantities of definite magnitude. Thus we proceed from Kepler's laws to find the acceleration of a planet's motion. This is discovered to be directed toward the sun, and to be in magnitude inversely as the square of the distance. We may call it by the name Force if we please, but we are not to imagine it as an active agent. Something quite analogous appears in the equations of motion when we introduce the idea of Constraint. The mode in which the idea of Mass is introduced by Kirchhoff is peculiar. It is really equivalent to a proof (ultimately based on experiments) of Newton's *Third Law*. Once, however, it is introduced, the same species of reasoning (which differs but slightly from what we should call kinematical) leads to the establishment of D'Alembert's and Hamilton's *Principles*, with the definition of the potential function, the establishment of Lagrange's generalized equations, and the proof of conservation of energy, etc. The observational and experimental warrant for this mode of treatment is, according to Kirchhoff, the fact that the components of acceleration are in general found to be functions of *position* [Kirchhoff's view of Force has some resemblance to, but is not identical with either of, the views previously published by Peirce and by the writer.] This is the chief *peculiarity* of the book, and very different opinions may naturally be held as to its value, especially as regards the strange admixture of kinematics and dynamics.

GUSTAV ROBERT KIRCHHOFF.

Of the rest, however, all who have read it must speak in the highest terms. A great deal of very valuable and original matter, sometimes dealing with extremely recondite subjects, is to be found in almost every chapter. Among these we may specially mention the investigation of surface conditions in the distortion of an elastic solid, with the treatment of capillarity, of vortex motion, and of discontinuous fluid motion (Flussigkeitsstrahlen).

Besides these definite classes of papers, there is a number of noteworthy memoirs of a more miscellaneous character—on important propositions in the thermodynamics of solution and vaporization, on crystalline reflection and refraction, on the influence of heat conduction in a special case of propagation of sound, on the optical constants of aragonite, and on the thermal conductivity of iron.

Finally, we have the series of papers on radiation, partly mathematical, partly experimental, which, in 1859 and 1860, produced such a profound impression in the world of science, and which culminated in the great work on the solar spectrum whose title is given above. The history of spectrum analysis has, from that date, been one of unbroken progress. Light from the most distant of visible bodies has been ascertained to convey a species of telegraphic message which, when we have learned to interpret it, gives us information alike of a chemical and of a purely physical character. We can analyze the atmosphere of a star, comet, or nebula, and tell (approximately at least) the temperature and pressure of the glowing gas. But, at the present time, the fact that such information is attainable is matter of common knowledge.

This is not an occasion on which we can speak of questions of priority, even though we might be specially attracted to them by finding v. Helmholtz and Sir W. Thomson publicly taking (in full knowledge of *all* the facts) almost absolutely antagonistic views. However these points may ultimately be settled, it is certain that Kirchhoff was (in 1859) entirely unaware of what Stokes and Balfour Stewart had previously done, and that he, with the powerful assistance of Bunsen, MADE what is now called spectrum analysis—Kirchhoff, by his elaborate comparison of the solar spectrum with the spectra of various elements, and by his artificial production of a new line whose *relative* darkness or brightness he could vary at pleasure; Bunsen, by his success in discovering, by the aid of the prism, two new metallic elements. P. G. TAIT.

NORBERT RILLIEUX.

NORBERT RILLIEUX was born in New Orleans in 1806, and is the eldest son of Vincent Rillieux, owner of the first cotton press in this city; also the first to demonstrate the practicability of using stone pavement on our streets, having made the first one in his press yard, corner Poydras and Magazine streets—a thing which was before thought impossible. He also took an active part in the war of 1814–15.

In 1817 Norbert Rillieux was sent to France to be educated, and at an early age showed great aptitude for scientific studies. His articles published about 1830 in the journal *Le Temps* showed him at twenty-four years as the strongest mechanical engineer of his time. He had already been appointed professor of steam machinery in l'Ecole Centrale de Paris at the time of its formation.

Mr. Rillieux had a profound taste for invention, and about 1825 he conceived the idea of the compression of portable illuminating gas in forged retorts. He invented a steam engine with large foot boards, with two cylinders, with expansion in first, which unfortunately he could not carry out for want of means, although the idea was taken up later, under the name of compound engine.

In 1830 he invented his double and triple effects apparatus in vacuum. Then, French sugar usines employed only open air kettles with coils, in which high pressure steam was sent. In Paris there were but two constructors of these kettles, Moulfarine and Pecqueur, to whom Mr. Rillieux spoke of his new invention, but they did not understand its advantages, and found it too complicated for sugar manufacture, where the steam engine had not yet made its appearance. Then Mr. Rillieux saw that the French sugar industry was not far enough advanced to adopt his invention.

At this time he received a letter from Mr. Ed. Forstall, of the firm of Lizardi & Co., of New Orleans, stating that he had recently erected a large sugar refinery, which had been completed in six months, and they could not get it to work. He asked young Rillieux to come to his aid, offering him the appointment as chief engineer of the refinery. Mr. Rillieux thought to see in this the realization of his hopes, and that his native Louisiana would be the place for the erection of his first multiple effects apparatus. He left France after founding a professorship of mechanical engineering in l'Ecole Centrale de Paris, over which Colladon, then a young, distinguished physician, presided, and later on he engineered the magnificent tunnel of Mt. St. Gothard, in Switzerland.

Arriving in New Orleans, in eight days Mr. Rillieux had the machinery in running order. At the same time he made known to Mr. Forstall his idea of his double and triple effects apparatus, and also his project of draining the lowlands in and around New Orleans. This gentleman promised him to be his associate and backer, but, unfortunately for the young engineer, his father had had some business entanglement with Mr. Forstall, and when his father heard of the proposed alliance he dissuaded young Rillieux from having any further transactions with Mr. Forstall.

Mr. Rillieux's idea was to form a company for the purpose of the purchase and drainage of the low land around New Orleans. He proposed this to Mr. Laurent Millaudon and other capitalists, also to the owners themselves, but they all declined. Afterward, Mr. Mercier, brother-in-law of Pierre Soule, to whom Mr. Rillieux had often spoken on this subject, became alderman, and proposed, with the consent of Mr. Rillieux, an act for the accomplishment of this object at the common cost of the city of New Orleans and the State of Louisiana. Mr. Rillieux accepted these combinations and furnished his plans of machines and canals, etc., but Mr. Forstall, who had become an influential member of the legislature, was placed at the head of this company, another engineer was selected, and Mr. Rillieux was thus prevented from presiding over the great work he had created. The law was later declared unconstitutional.

Mr. Rillieux experienced great difficulty in placing his double and triple effect, owing to the fact that Mr. Forstall introduced in 1846 open copper kettles,* claiming that Rillieux was an engineer, but no planter, and did not know the need of the Louisiana sugar industry, and that it was useless to pay such a high price for a Rillieux apparatus when the open kettle answered as well. The first trials with these open kettles were not successful. The sugar was burnt and sold at half price, and consumed one cord more than with the *equipage*. The following year at the same plantation was erected a vacuum pan, and there was made fine sugar. Other sugar-producing countries, such as Cuba, and the beet sugar industry, have enriched themselves by adopting the Rillieux double, triple, and quadruple effect, which reduced the cost of manufacture by the fuel economy it produced.

Unfortunately, Louisiana alone remains in the rear of progress. Notwithstanding the drawbacks, Mr. Rillieux, in 1843, succeeded in erecting and operating one of his apparatus on Mr. Th. Packwood's plantation (now Hon. T. S. Wilkinson's) and obtained magnificent results. This apparatus made 1,000 hhds. of sugar instead of 800, which was produced with the same quantity of cane. The sugar was much finer and sold for seven cents a pound instead of four cents. The bagasse alone sufficed to make all the crop. Then many planters ordered these apparatus, notwithstanding the efforts of his opponents to introduce the French kettles. Each year Mr. Rillieux had numerous orders, until the beginning of the war of 1862, when he left America for Paris, there to devote himself to archæological studies, which for sixteen years occupied all his time

The history of the introduction of Rillieux's apparatus in Europe is interesting. About 1850, a German, Brami Androea, came to Philadelphia, and proposed to Messrs. Merrick & Town to show them how to build steam sugar apparatus (Degrand's) such as were employed at that time in his country, where he was engineer of a Magdebourg constructing firm. He did not know the Rillieux apparatus, and was surprised to find in America apparatus superior to those used in Europe, and having to construct a usine in Mexico, he ordered, immediately, a Rillieux apparatus. He was furnished with a double effect of evaporation, with a third horizontal pan, which was the cooking pan and which equally operated in double effect. Then Androea, profiting by the knowledge thus gained, made designs which he sold to the firm of Tischbein, of Magdebourg, who resold them to the firm of Cail & Co., of Paris, and thus the Rillieux apparatus penetrated in Europe. It is probable that Androea did not give to Tischbein all the necessary information as to the working of the apparatus of which he sold the designs, and especially did not indicate that the third pan was used as a cooking pan. As Tischbein and Cail used the third pan for evaporation, they drew most erroneous conclusions upon the differential reports that Mr. Rillieux gave to the different pans of a double effect; and it resulted in the books and publications at that time a great confusion, from which arose most erroneous theories. It transpired that the apparatus constructed at that time in Europe operated in a very defective manner. But later, Brami Androea returned to Magdebourg and operated as well as he could the three-pan double effect that Tischbein was constructing. Before, they never employed the cooking pan at double effect. This operation was made in separate pans, with which the usines were already provided. After Androea returned, the engineer who replaced him in Magdebourg went to Austria, where he likewise introduced the double effects, and this is why Germany and Austria, until the last few years, constructed but double effects.

In France, Cail, in the beginning, constructed double effects with three pans until Mr. Dureau, now proprietor of the *Journal des Fabricants de Sucre*, of France, returned from Louisiana, where he had taken off crops with the Rillieux apparatus, and it was probably under his advice that Cail & Co. constructed triple effects, and there, also, the cooking at double effect was abandoned for the same reasons as in Germany. But Mr. Cail did not understand the services that Mr. Dureau could render him, and did not know how to co-operate with him. Thus the triple effects that he constructed operated so badly that they were surnamed *triste effets*. It was in this condition that Mr. Rillieux found his apparatus in Europe, when in 1878, by chance, he met Mr. Dureau, and he then busied himself anew, wishing to render new favors to the sugar industry in restoring to his apparatus, so well maltreated, their normal working by applying to them the rational principles of evaporation that were totally overlooked; and, in fact, he took patents to modify the existing apparatus in Europe, America, and other countries, whereas it is Europe that furnished the models to the entire universe with their imperfections.

Since Mr. Rillieux left Louisiana, and the transformed apparatus had an increase of 50 to 100 per cent. in such a manner that a triple effect that was treating only 2,000 gallons per hour could make, with the Rillieux process, 3,000 and 4,000 gallons. Besides, the transformations are inexpensive; therefore, the Rillieux process has a great reputation. France, Germany, Austria, and Russia transformed, and are transforming each year, numerous apparatus on this process, finding a great advantage, doing more work in the same time with the same apparatus.

In Cuba, Australia, and Java, Mr. Rillieux had also some transformations to make, so advantageous are his processes, which are applicable as well to the horizontal as to the vertical apparatus, which are also his invention. One day, having made a sketch in the presence of Androea, to show him what form he would adopt for the beet sugar industry, whose apparatus clogged and needed frequent cleaning, Androea kept this sketch and, without doubt, showed it to Cail in France and to Robert in Austria, as at the same time both of them constructed the vertical pan apparatus, and disputed for a long time the priority. Thus it is that Mr. Rillieux has again endowed the sugar industry with a great invention and re-entered in the affairs of the industry at an age when one usually aspires to rest.

It is the multiple effect heating of the juices which allows a large economy of fuel in the usine, and this new application of multiple effect is rapidly spreading in Europe, where fuel is a large factor in the cost of making beet sugar. For the cane sugar industry, these processes will allow the planters to burn no other fuel but the *bagasse alone*, even in increasing greatly the quantity of juice extracted from the cane by the *diffusion of the bagasse* to obtain more sugar.

Such is the life of Mr. Rillieux, who ought to be honored with just title as the benefactor of Louisiana as well as the whole sugar industry.—*The South Illustrated.*

* Prior to that time the kettles were of wood with copper coils.

IRRIGATING MACHINERY ON THE PACIFIC COAST.*

By Mr. John Richards, of San Francisco.

In offering the present paper to the Institution of Mechanical Engineers, the author does so with a tolerably complete knowledge of the very advanced practice in England in this class of machinery; and his purpose is mainly to explain the differences that have been called for by local circumstances in California.

Character of the Country.—The western or Pacific slope of the Sierra Nevada or coast range of mountains in California is very abrupt, the crests of the range being so near that the snow is visible from the coast during the whole year. Hundreds of streams cross this narrow country, falling either direct into the Pacific Ocean or into the great basin formed by the Sacramento and San Joaquin rivers.

These two rivers, the largest in California, run in opposite directions, nearly parallel with the coast, and meet at the Bay of San Francisco, forming a continuous valley 400 miles long and from 50 to 100 miles wide. The small streams for the most part are fed by melting snow in the summer; and every gulch or canon has its rivulet or brook They increase in volume until they pass into or through the hills at the foot of the mountain range; and there, unless of considerable size, they may wholly disappear in summer by percolation through the silt or by evaporation. Streams exposed to the torrid air which in summer sweeps across the sand deserts of Southern California are dried up with wonderful rapidity. The evaporation from Salt Lake, exposed to the same dry wind, is sometimes equal to half an inch per day, or 64 million tons of water. Notwithstanding this great loss by evaporation, the quantity of water falling into the ocean on the coast of California has been estimated at 100 million cubic feet or $2\frac{3}{4}$ million tons per minute, enough, if distributed properly, to irrigate 25,000 square miles.

The Pacific coast in California may be said to consist of a mountain slope, fissured everywhere by water, and of alluvial plains formed by the sediment deposited from the water, which varies from coarse gravel and sand to fine silt, as the velocity and volume of the watercourses have determined. Nearly the whole country is therefore underlaid with strata of sand and gravel, which afford water everywhere at various depths. The need of irrigation arises from three causes – the lack of rain, which in summer ceases wholly along the coast, the want of surface water, and the free percolation into the sand beneath. The area requiring irrigation comprises most of the land in the country, except the low lying sedimentary plains near the mouths of the rivers and around the Bay of San Francisco, where water reaches the surface by capillary saturation.

Water Training.—In the days of placer gold mining, a large part of the running water in the mountains and foot hills was collected in extensive ditches, flumes, and iron pipes. The water was as important as the gold, which could not be washed out without it. Placer mining is gone; but the ditches remain, most of the water now being required for the more permanent business of fruit growing and other kinds of agriculture. Perhaps no part of the world equally rugged and difficult of access has been so thoroughly explored and mapped as this. From the tops of the mountain ridges to the depths of the canons there is scarcely an acre that has escaped the search for gold and silver.

The information thus acquired respecting the surface of the country was made use of as soon as agriculture began to receive attention; and the result is that nearly all land is now occupied upon which water can be led, not only by training small mountain streams, but also by leading long canals, or ditches as they are called, from the rivers, until at the present time, or when works now in hand are completed, the only remaining resource for getting water will be by lifting it from the rivers or the gravel strata by machinery.

Character of the Machinery Required.—The standard methods of raising water for irrigation and drainage, commonly adopted in the Netherlands and elsewhere, would not apply on the Pacific coast. Permanent foundations are wanting. A number of small separate pumping stations, widely distributed, are required, instead of a few large establishments centrally situated; and a high efficiency is essential in the machinery employed, because of the high cost of fuel, coals of indifferent quality being worth from 30s. to 40s. a ton. For raising 420,000 gallons per hour from 6 to 10 feet high the cost of the machinery is from £500 to £600. For raising 1,000,000 gallons per hour from 10 to 14 feet high the cost is from £800 to £1,000, including engines, boilers, pipes, and framing.

This must account for the light sections and other scant proportions that will be observed in the drawings. Material enhanced in value 40 to 50 per cent. by tariff taxes is, of course, used sparingly. An efficiency of 65 to 70 per cent. is attained in most cases when the head or lift is between 8 and 16 feet. For pumping from deeper wells the machinery is much more expensive in proportion to the quantity of water raised, both because of the greater length of the driving connections to the pumps, which are placed in the bottoms of pits in order to be within suction distance of the water, and also because of the greater strength required in all parts to stand the speed and pressure. Fruit farms, on account of the labor and attention they require, are limited in size; and irrigating machinery must come within moderate limits of cost. Where the water is drawn from the gravel, concentration of pumping is out of the question.

Percolation is not free enough to admit of large quantities being raised at one point and distributed; and even if this were possible, adjacent wells would be robbed, and litigation might ensue. In some experiments at San Jose, California, during the year 1885, it was found that, in drawing 15,000 gallons per hour from two artesian wells of 10 inches in diameter and 200 feet in depth, neighboring wells at distances of from 200 to 600 yards were lowered. In this instance the water rose naturally to $2\frac{1}{2}$ feet above the surface of the ground at the wells, and was lowered only 6 feet by drawing 15,000 gallons per hour. The wells here referred to, and indeed nearly all wells in irrigated districts, are tubes of sheet iron from 6 to 14 inches diameter, sunk by forcing, the earth being removed through the interior of the tubes. In the broad alluvial plains along the Sacramento River, and especially in places near to its banks, percolation is so rapid that some attempt has been made at concentration of pumping plants.

One well of 40 feet diameter and 16 feet depth, having an infiltrating surface of 1,000 to 1,200 square feet, yields 180,000 gallons an hour; and others of smaller infiltrating area yield a proportionate quantity. But these are in places where the water-bearing strata are much thicker than usual, the gravel coarse, and the saturation greater than in most other parts of the country.

Early Irrigating Machinery.—One of the earliest appliances for raising water in California was the Chinese pump, which consists of an endless band traveling round pulleys at top and bottom of a moderate slope, and carrying a series of wooden floats or crossbars fixed on its outer face. The under span ascending through an open trough carries up water from a ditch or pit, and delivers it into a launder or flume at top. The endless bands are sometimes made of India rubber or of cotton canvas; but more commonly consist of a pair of ropes, upon which the crossbars, having their ends split, are clamped at regular intervals by means of screws. It is a very cheap contrivance, and for low lifts is still employed to a considerable extent by the Chinese and Italians. It was doubtless introduced into California by the Chinese in imitation of similar pumps extensively used in China for raising water from the canals, where the lift is only a few feet. For slopes not steeper than 20 degrees, and lifts of only from 3 to 6 feet, it is found to be very economical in cost of working; and is said to be capable of high duty when the wooden floats or crossbars are so arranged and proportioned as to render the rising span nearly buoyant in the water, and especially when the inside of the trough is lined wiih metal to diminish the friction. For irrigation these pumps are commonly driven by horses, and for other purposes are employed only temporarily; and so far as the writer knows, no experiments have been made to determine their real efficiency. For lifts exceeding 10 feet and slopes steeper than 30 degrees, the friction and leakage render them unsuitable; and their use is being abandoned as better methods are introduced.

Tube Well Pumps.—These pumps, or the method of constructing them, grow out of the oil well experience in the Atlantic States. A common method of working such pumps is by means of a beam and engine. The tubes or barrels, which constitute both well and uptake, are made of galvanized iron, from No. 18 to No. 14 B. W.G., or 0·05 to 0·085 inch thick, with the longitudinal seams riveted and soldered together throughout. They are made from 6 to 14 inches in diameter, and are sunk to depths varying from 100 to 200 feet, sometimes more when pure water is wanted. The water rises in the wells to heights varying with different seasons, and in some cases overflows at the surface, as in the well at San Jose already mentioned.

The pumps are placed at different depths accordingly. For irrigation the wells are generally arranged in a quadrangle when there are four; or when there are two, the distance between them is from 10 to 20 feet. The distance apart does not seem to be a matter of much importance: in pits the same kind of tubes are put down within a few feet of each other. These crude-looking pumps are much more effective and economical in their working than would be supposed. The pump rods are of wood, their section being equal to half the area of the working barrel; consequently, in both the up and down stroke the delivery is equal to half the capacity of the barrel. In effect, therefore, the pumps are double acting, with only one set of valves, and the load is in a measure equalized between the up and down strokes. They correspond with the ordinary bucket and plunger arrangement common in mining districts.

The working barrel is either a brass casting bored out or made of drawn brass tube. The foot valve at bottom is inserted from the top, and can be drawn out and replaced without trouble, after the pump rod and bucket valve have been removed.

The two tube wells of 10 inches in diameter at San Jose, already mentioned, were put down by contract for 5s. per foot for the first 100 feet, including everything. For a second 100 feet the cost per foot would be something more, not exceeding 50 per cent. extra, and generally less, according to the nature of the ground to be sunk through. Wells from 7 to 8 inches in diameter, and not exceeding 150 feet deep, cost from 4s. to 6s. per foot, including galvanized tubing inserted ready for use. Much depends, of course, on the nature of the ground; and if bowlders are met with, the whole work may be lost. It is not easy to withdraw the tubes, and in case of obstruction they are generally abandoned. A serious impediment to the use of these pumps is the wear of their valves or leathers, which are soon destroyed by sand and gravel. To renew them, the pump rods of 50 to 100 feet length have first to be removed by drawing them up and disconnecting the sections one at a time. As the rods

* A paper recently read before the Institution of Mechanical Engineers, London.

are long, heavy, and inconvenient to handle, half a day's time of two men may be required to replace a leather which will not last twenty-four hours after it is inserted.

Accordingly, for pumping from the sand and gravel strata the author is of opinion that no machinery which involves close fitting pistons or sliding joints of any kind exposed to the water can ever succeed in California.

Centrifugal Pumps.—The destruction of pistons by the sand and gravel has led to the adoption of centrifugal pumps. In these, with their constant and rapid flow, the sound of the gravel striking against the elbows and sides of the pipes can be heard distinctly. A pile of gravel and coarse sand soon accumulates wherever the speed of the discharged water is slow enough to allow of precipitation; and the wonder is what supplies the displacement thus caused at the bottom of the wells.

Elsewhere it has not been common to recommend centrifugal pumps for high lifts, and they have been considered less economical than piston pumps; but the opinions hitherto entertained regarding them have been much modified by the experience of their working in California. A head of 100 feet, however, for a centrifugal pump to work against, is a very different thing from a head of only 10 feet. The impact or mechanical push of the vanes, which is a very important factor, diminishes as the head increases and as the relative speed of the vanes and water varies. When the head exceeds 40 feet, efficiency declines rapidly, but not to such an extent as to outweigh the great economic advantages of centrifugal pumps for heads up to 100 feet, or even more. For lifting water from the gravel strata in California, four kinds of centrifugal pumps have been employed, viz.—first, the common make with open vanes revolving in a plain volute casing; secondly, wheels with shielded or incased vanes, the water being drawn in at the center and discharged from the circumference; thirdly, compound pumps with two or more wheels acting in succession upon the water during its passage through the pump; and, fourthly, balanced pumps receiving the water at one side, whence it is deflected in an easy curve to the circumference by a conical disk on which are formed the vanes. These various forms of the centrifugal pump may be regarded as phases of development, adapted in some cases for particular objects, but usually reverting from inclosed disks, compound or double wheels, and other features, back to the original simple form of the first pumps in use prior to 1820. The wheels with incased vanes, for example, have been a feature of first practice with most prominent makers. These wheels were made in America as early as 1831, mainly with the object of partly avoiding side thrust when a single inlet was employed.

Centrifugal Pumps with Open Vanes.—These are employed for lifts up to 30 feet, and are usually arranged at the bottom of rectangular pits sunk to the depth required for bringing the pumps within suction distance of the water. The pits have often to be sunk 50 feet or more below the surface, and are usually 10 to 12 feet long and 4 to 6 feet wide. The sides are lined with planks of redwood (sequoia), which is very durable under exposure in such situations. Two or more tube wells are sunk from 50 to 150 feet below the bottom of the pit, and in them are placed suction pipes, connected by bends at the top to the upper side of the horizontal pump casing, as shown in the drawing. This mode of connection is adopted simply for convenience in the present case, in which there is no upward thrust; but for a different and more important purpose in other cases to be described presently. The pump is driven by a vertical shaft, which is mounted in pivoted bearings, having a supporting collar for carrying the weight of the shaft and pump wheel. The compression couplings for connecting the several lengths of which the shaft is made up are so constructed as to be almost instantly loosened or removed. These couplings were introduced in England a short time ago by the writer, and have given evidence of superiority over the more intricate modifications that have preceded them. The uptake or rising main from the pump is of galvanized iron, and preferably two to three times as large in area as the delivery nozzle on the pump.

The pumps are charged in several ways, always from the top of the pit. There is a steam ejector with a small pipe running down to the pump. Air pumps are sometimes used. Charging with water is out of the question, because foot valves are no longer employed. It was found that the rapidly entering water, loaded with sand and gravel, cut away the valves like the sand blast process; and there is no room in the well, as there is above, for making flap valves that swing clear of the current. Single acting engines have been found most suitable for driving these pumps, and are now extensively adopted for the purpose, being connected with the top of the vertical pump shaft by a band. For some of the earliest pumps horizontal driving shafts were employed, with bands extending down the pit from a shaft at top to the pump at bottom; but the weight of the bands, the danger to any one descending the pit, and the delay caused by breaking, rendered that plan undesirable, and it has given way to vertical driving shafts.

One of the first experiments in deep pumping with a centrifugal pump was made in a case where the water stood at 70 feet below the surface; and when it had become lowered by pumping, the lift was 74 feet. The pump was a compound one, driven at 900 revolutions a minute, raising 10,000 gallons an hour. The pit was only 3½ feet square, and the pump was fixed at 60 feet below the surface. A band passing down the pit was employed for driving; but the difficulties attending its use were such as to direct attention to other and safer methods of transmitting power in deep pits.

Centrifugal Pumps with Shrouded or Inclosed Vanes.—Nearly all makers of centrifugal pumps in California and elsewhere have at first followed Sir Henry Bessemer's plan of more than thirty years ago, employing shrouded wheels, in which the sides of the vanes are attached to two inclosing disks that revolve with them. The difference is very great between a wheel or runner constructed in this manner with closed sides and an open wheel without inclosing disks attached to the vanes.

With the shrouded wheel a water tight joint must be maintained all round the inlet orifice; otherwise the water would only circulate through the pump, passing from the circumference back to the inlet. Such leakage is increased by the pressure, which at all points on the sides of the wheels is the same as in the discharge pipe or at the discharge orifices of the wheels. The skin friction of the water seems to be less with a shrouded wheel; the water, instead of being driven round in contact with the sides of the stationary casing, flows through the wheels as it does through the pipes, without any greater skin friction in passing through the wheel than for an equal distance in the pipes. On the other hand, however, there is the skin friction of the outside of the wheel itself; and this has been found to be diminished by having a considerable thickness of water intervening between the outside of the revolving wheel and the inside of the stationary casing. There is only a very narrow clearance space at the sides of the wheel; but unusual care has been taken in construction. The wheel turned and made perfectly true after being keyed on the spindle.

The resistance greatly increases if the wheels are not perfectly true; but up to the present time the data respecting friction in such cases are meager. Experiments now being made in the University of California, it is hoped, will before long afford useful facts respecting the friction of submerged bodies revolving at high speed. As the water enters through one side only of the wheel, it causes a thrust in that direction, which is equivalent, not to the force of suction only, as is generally supposed, but to the whole duty performed, including both suction and delivery. The pump being inverted, with the suction inlet at the top, the entering water flows downward, and the reactive force is consequently upward. The upward thrust, which in most cases would be objectionable, is here turned to practical account for supporting the weight of the vertical driving shaft and the pump wheel. The amount of the thrust was at first computed as the area of the inlet multiplied by the head of the suction lift. But it was soon found that the reactive force was equal to the driving power or the pump duty; and weights had accordingly to be added for compensating the upward thrust.

The plan of inverting the pump so that the suction enters at the top was introduced in California by the writer in the latter part of 1883; and he believes it will be of great importance in future, because of the difficulty of supporting the vertical driving shafts by other means in the deeper pits. In the case of one pump, completed a short time ago, the weight of the shaft and its attachments was nearly 2,000 lb. The shaft was of steel, 2¼ inches in diameter, and ran at 600 revolutions a minute. The upward thrust was sufficient to carry this shaft, together with some additional weight which was found necessary. The lift was 90 feet, inlet of pump 10 inches in diameter, throat of discharge 5 inches in diameter, uptake pipe 10 inches in diameter. This problem of thrust upon inclosed wheels taking water at one side is an intricate one. If the rear side of the wheel is exposed, as is common, to a pressure equal to the discharge, the thrust is the inlet area multiplied by the discharge pressure. If the wheel is shrouded on one side only, the thrust will be equal to the whole area of the wheel multiplied by the discharge pressure. At starting there is of course no upward thrust until the pump is charged. Provision is therefore made for carrying the shaft on collars, which are already required for steadying the revolving wheel laterally in the pump casing, and are so arranged as to support the shaft vertically for a short time, unassisted by the water thrust. The collars are screwed upon the shaft, and several thin washers of steel are inserted between them and the seat which carries them. They run in a pool of oil, or rather oil and water, because there is generally a small pipe leading a little water back from the discharge pipe to the thrust box. The joint thus formed seals the pump, taking the place of a packing gland.

It was with some misgivings that the writer first ventured to substitute this contrivance for a packing gland on the suction side of a pump; but thus far it seems quite as reliable, and requires no care or adjustment. The suction pipes are commonly arranged for branches leading in from right and left; their large area is intended to be equal to that of a number of branch pipes, and to keep the flow in all at a uniform rate as nearly as possible.

Compound Centrifugal Pumps.—Two of the main problems to be dealt with in applying centrifugal pumps to high lifts are how far the impact or mechanical push of the vanes may be disregarded as a factor in the pump's duty, and how the bearings and driving gearing may be maintained in proper order at the high speed required. Practically, the speed at which the pump should be driven increases as the square of the height of the lift. For example, the circumferential speed of the revolving wheel for a lift of 60 feet will be at least six times as fast as the discharge column should flow; while for a head of 80 feet the circumferential speed for the same flow would have to be more than ten times that of the discharge current. It is therefore seen in how rapidly increasing a degree the revolving wheel must overrun the flow as the lift increases, and how rapidly the effect due to impact or mechanical push of the vanes falls off, as the velocity of the wheel increases. For lower lifts the extent of overrunning diminishes in the same degree, and the gain by impact is increased accordingly.

It is easy to attain high efficiency in centrifugal pumps working against a low head; but it is a difficult matter to arrange such pumps suitable for working in the deep pits in California, against a pressure of 43 lb. per square inch or 100 feet total lift, and to secure results that are satisfactory. Thus far it has not been possible to make experiments for determining definitely the efficiency attained in these high lifts. From such observations as have been made, it would seem that from 35 to 45 per cent. of the indicated power has been realized in water raised. As the pits are too narrow to admit pumps with volute casing and with a single wheel large enough to attain the required speed, the pumps have to be compounded, so as to reduce the speed of rotation and diminish the size of the wheels and casing. In a compound pump with two revolving wheels, the main casing is made in five parts, consisting of three hoops or rings and two intervening diaphragm plates, all secured together by external bolts. The driving shaft from the top of the pit is coupled to the pump spindle. A charging pipe is carried down from the top of the pit. The foot of the delivery main is surrounded by an annular air vessel. The water is drawn by suction into the top chambers, whence it passes downward through the two wheels on runners, and out through the discharge chamber, the delivery valve, and the rising main.

The two shrouded wheels have each five curved vanes. The exact shape of the curves is believed by the writer to be a matter of very little importance in practice; and the number of the vanes, whether two or six, does not make much difference in a high speed pump. Curved throatpieces and tangential tips to the vanes are found in such cases to be of practical value so far only as they tend to obviate friction and consequent slight loss of power. The diaphragm above the upper runner is a plain flat plate; but the intermediate diaphragm between the two runners is made with fixed guide blades on its upper side, for leading the water back from the circumference of the upper wheel to the central inlet into the lower. Besides a double inlet, two more inlet orifices are provided in the top cover for convenience of attaching additional suction pipes in different cases; but it is not often that all four inlets are required. The delivery valve is arranged to swing clear of the ascending column of water; the area of passage is here contracted, and determines the pump's capacity. In all other parts the area of passage is made much larger. Except for avoiding concussion from the water in stopping the pump, the air vessel may seem superfluous in a continuously acting pump. But it is not so, and air vessels are now applied by the writer in all cases for deep pumping. The seat of the delivery valve is raised so as to leave an annular space all round it, for catching any gravel deposited in the valve chamber; this space is commonly made much larger than shown in the drawing. The bottom bearing of the pump spindle is simply a hole bored in the base plate. There is no strain upon it when the wheels are carefully balanced. It is, of course, exposed to sand and gravel, but these do not seem to have much effect upon bearings of steel running in cast iron; either the sand is at once pulverized and washed out, or in some other way attrition is prevented. Similarly, the throats of the inlet orifices in the revolving wheels do not seem to wear after they have ground themselves out of contact.

Triple Compound Centrifugal Pump.—In a triple compound pump designed for the permanent duty of raising 3,000,000 gallons of water per day through a lift of 70 feet for a town supply in California, the suction pipe is connected with the bottom of the pump casing, and the water entering ascends through an inlet orifice in the under side of the bottom runner, from which it is delivered to the top of the pump, and thence passes downward through the two upper runners, and from the lower of them to the delivery pipe. Two of the three wheels balance each other in vertical thrust; and the upward thrust of the third will be sufficient to support the steel driving shaft of 2½ inches diameter, together with all its mountings, the whole weighing 1,800 to 2,000 lb. In one instance the working of a compound centrifugal pump has been interfered with by the liberation of carbonic acid gas in the suction pipe, owing to the vacuum of 6 or 8 lb. per square inch below the atmosphere. The presence of such gas in artesian water had previously been suspected, because of a constant accumulation of air, as it was supposed to be by those in charge of the pumps. The difficulty is easily overcome by providing vent for the gas at the highest point in the discharge chambers.

(*To be continued.*)

IMPROVING THE MAIN DRAINS IN FEN DISTRICTS BY MEANS OF SCOURING DREDGERS AND THE TRANSPORTING POWER OF THE WATER.

By W. H. WHEELER, M.I.C.E.

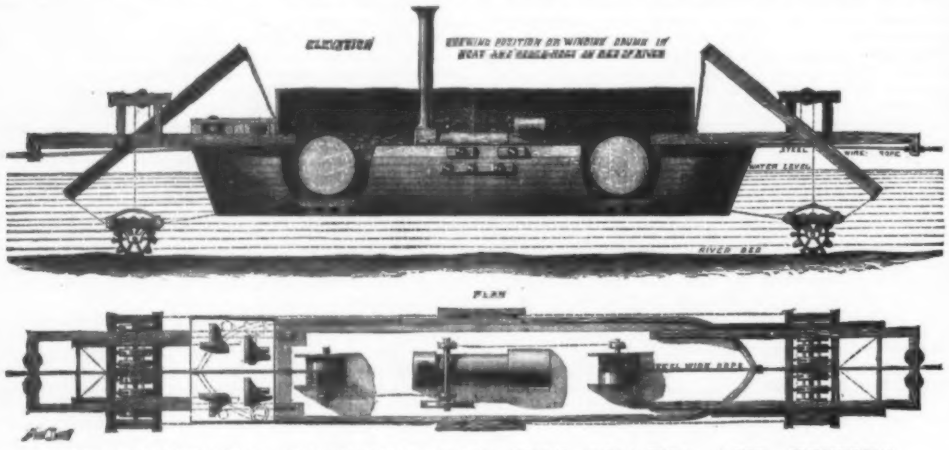
DRAINS running through fen and flat districts where the current is never very rapid, and where generally in summer time there is no current at all, are liable to become choked with weeds. The earthy matter carried by the water in suspension in floods is arrested by these weeds, and gradually a deposit accumulates at the bottom of the drains, in which more weeds grow, and so accretion goes on. The uniform depth of the channel is thus deranged, the bed of the river rises, and consequently the waterway and the discharging capacity of the drain is diminished. The weeds themselves also prove a great obstruction to the flow of the water. Accumulation of deposit also takes place across the main drains at the places where the lateral drains come into them. It is generally the practice to cut the weeds twice or three times a year. The ordinary method is by an implement resembling a number of scythe blades joined together, which is drawn backward and forward across the drain by men stationed on either side of the drain, and working upward against the stream. The weeds as cut are drawn out by rakes and placed above the highest flood level. A more effectual plan, and one which at the same time removes shoals and accumulation of deposit, is by loosening and breaking up the bottom by means of a revolving implement drawn along the bottom of the drain at the time when a current is running down. By this means not only the soil of the shoals is broken up and carried away in suspension, but also the roots of the weeds are torn up and carried by the current out of the drain. If this is done frequently, drains can be successfully kept clear of weeds and deposit, and may even be deepened at less cost than by dredging or by spade labor, without any injury to the outfall. Too little advantage is taken of the capacity of the water as a carrying agent in the improvement of rivers. In dredging, the chief expense and difficulty is the removal of the material dredged up. By continually stirring up the matter to be removed it rises in the form of mud, and the particles are sufficiently small to be moved and carried away in suspension. If the section of the channel is uniform, the velocity of the water will carry the material entirely away; but wherever there are wide places and slack currents, there will be a tendency for the matter in suspension to be deposited. By frequently and continually running the machine up and down the drain within the defined limits of the waterway, a uniform and regular channel can be maintained free from shoals and weeds.

The transporting power of water may be realized by considering the turbid condition and immense quantity of matter carried down by comparatively sluggish

streams in times of flood. The quantity of material transported by such rivers as the Humber and the Trent is evidenced by the fact that the warping lands on to which the water is allowed to flow and subside are raised at the rate of 2 ft. to 3 ft. in a year, owing to the constant change in the direction of motion of the water causing horizontal and vertical eddies. There is a considerable upward vertical action which counteracts the downward motion of particles of matter of heavier specific gravity carried in suspension. Particles of soil are thus kept suspended which in still water would fall to the bottom. In addition to the matter carried in suspension, the action of the water rolls along the bed of the channel particles of material the specific gravity of which is too great to be carried in suspension. A stream running with a velocity of 6 in. a second, or about one-third of a mile an hour, will transport soft clay; a velocity of half a mile an hour will carry sand as large as linseed; a velocity of two-thirds of a mile will sweep along fine gravel; while a current moving at the rate of a mile and a half an hour will roll along rounded pebbles; and at the rate of two miles an hour, pebbles the size of a hen's egg will be moved along the bottom of the channel.

In some rivers upward of 2 per cent. in weight of the total volume of water passing along their channels used at different times, both in this country and abroad.

The machine already referred to as being in use in the river Welland and the Deeping Fen drains has been designed and brought into practical use by Mr. Alfred Harrison, superintendent of the Deeping Fen drainage district, and consists of a barge to which, from framework projecting from both ends, is suspended a "hedgehog," or revolving drum, on the periphery of which are spear-headed blades. The barge is moved along the channel by means of steel ropes anchored in the bank at each end, and the other working round drums in the boat, similar to those used for steam plowing apparatus. The drums are made to revolve by gearing attached to a semi-portable engine in the boat, the one drum uncoiling and the other coiling up the rope. The drums or diggers are balanced by chains passing over pulleys to counter-balance weights, so as to enable them to rise over any substance too hard for the spades to penetrate, and undue strain on the ropes is thus prevented. The barge travels at the rate of about two miles an hour. The framework to which the "hedgehogs" are attached can be moved laterally by means of a windlass to each frame—see drawing—and thus act as a steering apparatus, by means of which the boat travels round very sharp bends without difficulty. The spades are placed alternately, and only enter a short distance into the bed of the stream. By the constant travel of the two "hedgehogs" up and down the drain, the soil is broken up sufficiently small for the whole of it to float and be carried away by the water. A perpetual churning motion is carried on by the fore and aft rollers, and the water being breasted up by the fore roller, causes a thorough mixture of the soil with the water, the earth being converted into sludge. Although silt and sand can easily be removed, a greater effect is obtained with a clay bed, from the lighter specific gravity of this material.



THE SCOURING DREDGER FOR FEN DRAINS AND RIVERS.

consists of material carried in suspension. The proportion in the Durance and the Vistula in floods is $\frac{1}{11}$. In the Garonne, and the Rhine in Holland, $\frac{1}{100}$; the Rhine $\frac{1}{310}$; the Po, $\frac{1}{300}$. In the other rivers the proportion varies from the above as a maximum to $\frac{1}{17000}$ as a dry weather flow.*

To give an illustration of the quantity of material transported by a river, it is stated that the Durance transports in one year 17 millions of tons of earthy matter.† The river Witham, in Lincolnshire, before the recent improvements were carried out, passed through beds of shifting sands at its mouth. The tidal flow was stopped by a sluice across the river about eight miles above the mouth, and consequently the ebb was very sluggish when there were no land floods running down, the tidal water entering the confined portion of the river at the rate of from three to four miles an hour. During the dry summer of 1868, when there was no fresh water flow down the river, the amount of sand brought up and deposited along the bed of the river was calculated to be $1\frac{1}{2}$ millions of tons, the whole of which was removed and carried back to the outfall when the winter floods came.

Allowing $\frac{1}{700}$ as an amount that could be carried by a stream without overloading, this would be equal to about 0·09 lb. in every cubic foot of water.‡ Taking a main drain having 30 ft. bottom, slopes 2 to 1, depth of water 8 ft., velocity one and a half miles an hour, the quantity of earthy matter carried in suspension would be 117 tons an hour, as follows: The area is 368 ft., velocity 132 ft. per minute.

$$\frac{368 \times 132 \times 0{\cdot}09 \times 60}{2240} = 117{\cdot}12 \text{ tons}$$

an hour. Allowing ten hours for a working day, 1,171 tons of earth, if loosened and broken up in the form of mud, would be carried away by the water. As a practical illustration of the working of this system, the dredger employed by the Deeping Fen trustees, hereafter described, was employed in cleaning out the Vernatts drain, which receives the water pumped from Deeping Fen, in Lincolnshire, containing 30,000 acres. The velocity of the stream where the dredger was at work varied according to the state of the tide in the river Welland, being very sluggish at high water, and increasing to about $1\frac{1}{2}$ miles an hour at low water. The boat was employed on a section 170 chains in length for eleven weeks, and during this time the whole of the weeds and mud accumulated on the bottom of the drain, together with a portion of the bottom of the drain consisting of clay, in places very hard, was broken up by the dredger and transported by the water free and clear, not only of the drain itself, but also of the channel of the river, and deposited in the estuary ten miles distant. The total cost of working the boat—for labor, coals, oil, etc.—was £65, equal to about 7s. 6d. per chain. It was estimated by Mr. Harrison, the surveyor of the district, that to have done this work by spade labor would have cost £200.

In the river Welland, by the aid of this machine, a length of 24 chains was deepened 2 ft. for a width of 17 ft. in three days' working.

In the river Glen the channel was deepened 3 ft. 6 in., with a slow current running, the soil being stiff clay.

Several appliances for breaking up shoals and loosening the beds of streams have been brought out and

To the foregoing on this subject by Mr. Wheeler we may add the following general account of expenses of working the "scouring dredger" in the Welland and Vernatts drains, 1885-6-7, which is a report to the Deeping Fen drainage trustees, April, 1887, by Mr. A. Harrison, superintendent, Deeping Fen drainage:

"The boat went to the Welland about the beginning of December, 1885, and was kept working up to the end of June in the following year. A succession of minor floods rising only to the top of the Cradge bank proved favorable for the operation, this being the real commencement of the stream dredger over 'miles' distances. The outfall or lower end was first attempted. First one mile, then three, five, six, and seven were traversed; and during all this time it was seen that black muddy water passed the Spalding high bridge as freely from Parr's Gull as from the Locks Mill. The success that has followed, and the great change effected in the channel of the Welland where the boat has been working the dredger in the Welland over the seven miles length, or nearly this, from the high bridge to Mr. Robert Smith's farm, or two miles from Crowland, was as follows:

"For the year 1886, £66 2s. 8d., and for the year 1887 £76 1s. 11d., making together £142 4s. 7d. This will cover the actual working expenses for all the work done in the Welland from December, 1885, to the present time. Taking £140 as the cost of the whole, but dealing only with the six miles above the Locks Mill; as 6 by 80=480 chains, the £140 divided by this will give a sum of about 6s. per chain throughout; and with 1s. for interest upon the outlay in fitting the boat, will give a total of 7s. per chain, with no risks of dams, or strikes with workmen. It is thus shown that by no known method could the Welland have been improved at so small a cost, and no further answer is for a moment needed to those persons who have hitherto refused to see the truth.

"*The Vernatts Drain.*—The boat has been working some eleven weeks over 170 chains, in the middle portion of this drain. Not only is all the mud gone over this length, but a good deal of the hard bottom, and portions of this were very hard indeed. The cost of the time of working the boat for labor, coals, oil, haulage, and all requirements, may be set at £65, as nearly as can be ascertained; thus, £65 divided by 170 chains equals about 7s. 6d. per chain for a drain 20 feet wide, and through the most difficult and expensive lengths of the drain. To estimate the value of the work, if done by spade work, at £200 is well within the mark, though the tides interfered very much with the onflow of the water and checked the scour.

"*In the River Glen.*—The boat is now employed working down the great shoals and hummocks in the river at Stóne Gowt, and is doing good work, forming and shaping the channel where the great scour holes have been left by the action of floods down the river.

"Owing to the *crooked formation of the channel* the work is more difficult to carry out, but by arrangements of anchorage it can all be done. One of the most crooked and tortuous channels in existence, but effectually done."

The effect in the river Glen has been considerable since this report was issued. Three feet of solid clay has been scoured away over portions of the river bed. The boat will proceed with the upper part of the river directly the rainy season begins and the flow of water commences.—*The Engineer.*

operating, cannot fail to place this trust in altogether a new position, and must relieve it from a source of annoyance and heavy expense. However effectually the cleansing of the river may be done by spade work, one dry summer will to a great extent neutralize all such efforts. The tides are again filling the channel and creating fresh work for the dredger, September 15, 1887. The silt left by the tides, within a very short period after the last contract was completed, would have cost to remove by spade work at least £250, over the four miles previously cleaned. The cost of

NEW STEAM CARRIAGE.

The new steam carriage figured herewith is mounted upon three wheels. The two large wheels are 4 ft. in diameter and the small one $2\frac{3}{4}$ ft. In front of the seat there is a small boiler which is heated with petroleum, which has no chimney, and which gives out neither smoke nor odor. Within the seat there is a reservoir of petroleum that holds 10 quarts—a sufficient supply to last for a trip of ten hours. Just behind is a water reservoir holding a little over 4 gallons—a supply sufficient for a trip of two hours and a half. This reservoir is divided into two compartments, one of which contains cold water and the other one water constantly heated by the waste steam. The hot water reservoir serves to supply the engine, and the cold water one serves to condense the steam, while passing through a village, for example, or when in the presence of a frightened horse. The maneuvering is effected by means of a cock placed alongside of the rider. In the extreme rear is the motor, weighing 88 lb. This motor is a vertical one, and has two cylinders $2\frac{1}{2}$ in. in diameter, with a piston stroke of 4 inches. It is placed in the rear so as to balance the weight of the boiler, for the water and passengers, which are variable weights, are placed directly over the axle. With the exception of the boiler, which alone is in front of the passengers, the parts are inclosed in a box to protect them from rain and dust. On top of this box, and within reach, are fixed various cocks that permit of emptying the cylinders, feeding the boiler, condensing the steam, changing speed, etc., without changing place. Within reach of one's left hand there is a supplementary brake, to be used in case the foot brake should fail to act. Within reach of one's right hand there is a steering handle which controls the front wheel very perfectly.

NEW STEAM CARRIAGE.

Finally, between the passengers, is the steam pipe, which slides from right to left along the seat so that the rider can sit in the middle if he is alone and always have the pipe under his control. The petroleum is introduced into the burners while the carriage is running, and at the will of the rider. The boiler is of copper, and is 16 in. in diameter and $14\frac{3}{4}$ in. in height. It vaporizes 2 gallons of water per hour. The heating surface is obtained through eighteen vertical tubes heated through radiation by means of petroleum burners. At the upper part of the boiler there is a heat

* Geike's "Geology."

† "Irrigation in France," Trans. Instit. C. E.

‡ Allowing 7,000 grains, or 1 lb. avoirdupois, and that a gallon of water weighs 10 lb., this would give 70,000 grains in a gallon. Taking the proportion of $\frac{1}{700}$ would give 100 grains of earthy matter to a gallon of water; or taking the cubic foot of water at 62·5 lb., and the same proportion would give $\frac{62{\cdot}5}{700} = 0{\cdot}08928$ lb. in a cubic foot of water.

box in which a steam worm and a feed water worm absorb the heat lost in the tubes. Immediately beneath the boiler is the burner box, which is provided with eighteen burners corresponding to the tubes. This box is 4 in. in height and 14 in. in width. The driver can, at will, increase or reduce the intensity of the flames, or put the latter out merely through the maneuver of a single lever. The burners are lighted in fifteen seconds and at once develop their entire heat. In fifteen minutes the boiler is under pressure, and the carriage is ready to start.

To prevent currents of air occasioned by the speed, the air for the burners is taken in at the base and in a direction opposite that of the carriage's running.

With one passenger this carriage is capable of making from 9¼ to 10½ miles per hour, and with two persons from 8⅛ to 9½.—*La Nature.*

THE NEW RAILROADS OF EASTERN EUROPE.

PUBLIC attention, since the *coup d'etat* of Philippopolis in 1885, has been again attracted to the East. It will perhaps not prove uninteresting if we point out what, from an economical, industrial, and commercial standpoint, is to be the situation created in Eastern Europe by the finishing of the system of railroads.

In order to understand what follows, it is indispensable to go pretty far back. We shall, however, make the historical *expose* of the subject as short as possible.

After the Crimean war, a long programme of internal reforms was submitted to the counselers of the Sultan by the European powers desirous of preventing a recurrence of the difficulties that the Ottoman empire had just escaped. For us, the most important part of this programme is that which relates to the creation of ways of communication designed to connect Constantinople and Salonica with the chief cities of Central and Western Europe by rail. A great length of time was in vain employed to conquer Oriental inertia, and it was not until Sultan Abdul Azis made a trip to Paris in 1867, on the occasion of the Universal Exposition, and personally saw the advantages of quick transportation, that the cause of railroads was gained in Turkey.

Vienna, through its situation, was the place naturally designated to become the objective point of the lines to be established. Two Austrian systems ended at that epoch on the Ottoman frontier. One of them (the *Südbahn*) stopped on the frontier of Bosnia, and the other (the *Staatsbahn*) ran toward Roumania, with a branch upon the Danube toward Servia. It was in these two directions that the general plan of the Ottoman lines was arrested. The road which was to unite with the *Staatsbahn* was the first one established from Roustchouk on the Danube, opposite Giurgewo, the terminus point of the Roumanian lines at Varna on the Black Sea. From thence passengers had to go to Constantinople by boat.

The want of a bridge over the Danube necessitated a transfer from Giurgewo to Roustchouk, and the trip by sea from Varna to Constantinople was tiresome. This was, and is still yet, the route most followed, although, as we shall see further along, it is now possible to avoid the journey by sea to reach Constantinople. In other directions, the direction lines fixed by the Ottoman engineers were indicated as follows: One line was to start from Constantinople, pass through Adrianople, Philippopolis, and Nich, and end at the Danube after crossing Servia; another one, leaving Salonica, was to pass through Macedonia, old Servia, and Bosnia, and branch off at the *Südbahn* to the frontier line of the Save.

In 1869, the Ottoman lines as a whole were conceded to Baron Hirsch, and, in order to pay the expense, a loan of $160,000,000 had to be effected through the intermedium of that financier. This loan was to be used in the construction of 1,200 miles of railroads. The work was at once begun, and in 1872, in consequence of a lack of money, the Ottoman government signed some new agreements with Mr. Hirsch that annulled those of 1869.

The grantee was relieved of a portion of the burden that had been imposed upon him in the first place. Although the lines traversing mountains were abandoned, the mean cost per mile of say $66,000 remained the same. The Turkish system was finished under such circumstances on the eve of the Turko-Russian war of 1876, the Salonica line ending at Tuitrariza, and the Constantinople line not extending beyond Bellova.

It was in such a state that the treaty of Berlin found the means of communication open in the Balkan peninsula in 1878.

Servia, which had become independent, and Bulgaria, independent in government, but a province of Turkey, were substituted for the latter to fulfill the obligations that had been contracted by the Porte in view of the construction of the railroads.

The Conference of Four, which met at Vienna for the purpose of selecting the direction lines, abandoned the line projected through Bosnia and Herzegovina, territories occupied by Austria, and fixed the starting point of the great road from the East to Budapest. From this point, a line started toward the south, that reached the Hungarian frontier of the Save at Semlin, entered Servia at Belgrade, and then ran to Nich. Here it branched on the one side toward Vrania, in order to connect (at a point to be determined) with the Salonica line at Mitrovitza, and on the other side to run through Pirot, Tsaribrod, Sofia, and Vakarel to join at Bellova the line that was in operation as far as to Constantinople.

Hungary got quickly to work, and the Budapest-Semlin line was definitely opened in the month of December, 1883. A bridge over the Save, between Semlin and Belgrade, was built by Fives-Lille at the mutual expense of Hungary and Servia. As for the Servian system, that was conceded in 1881 to Mr. Bontoux.

In 1882, it was feared that the bankruptcy of the General Union might compromise the Franco-Servian work; but the Comptoir d'Escompte, of Paris, and the Landerbank, of Vienna, took up the treaties concluded by Mr. Bontoux, and brought the Servian lines out all right, and they may now be considered as finished.

The first section, from Belgrade to Nich (146 miles), was opened for operation in September, 1884; that from Nich to Lescovatz (26 miles) in February, 1886; that from Lescovatz to Vrania (40 miles) in October of the same year; and finally, that from Nich to Bela-Palanka (26 miles) in June, 1887. The opening of this latter section as far as to Pirot is to be effected immediately. We may add that a branch constructed originally for facilitating the supplying of materials for the Belgrade-Nich line, between Semendria, on the Danube, and Velika-Plana (54 miles from Belgrade), likewise was opened for public service in November, 1886. Finally, the Servian government constructed another branch of 15 miles to connect Lapovo (64 miles from Belgrade) with Kragoujevatz, where there is a large arsenal. This branch is operated by the minister of war.

During this time, the Bulgarians, who have 69 miles to construct, have not hurried themselves. Bulgaria has to have recourse to credit, and the various political events that have been occurring for a few years past have not helped the solution of the problem. However, a little more activity is now displayed at the working points, which are directed by the Bulgarian firm of Groseff & Co. Money is always wanting, and it is to be feared that the indecision that continues to reign over the fate of this unfortunate country may prevent financiers from closing contracts with a country of doubtful stability.

On another hand, as long ago as 1885, a society called Raccordements Turcs was formed at Paris for the purpose of constructing lines from Bellova to Vakarel and from Vrania to Uskup. This society, at the head of which was the Comptoir d'Escompte, has finished its labors.

Upon the whole, of the two great ways of communication projected toward Constantinople, the first alone is finished. The finishing of the other cannot be hoped for before the end of next year, at the soonest.

Although the line toward Salonica is finished, the date of the opening of the Vrania-Uskup section has not been decided upon. Turkey, which is not on very good terms with Baron Hirsch, is not disposed to concede to him the exploitation of the said section. Per contra, a 54 mile line cannot give rise to the organization of an exploiting company. Very probably, the French company of Raccordements Turcs will buy the Ottoman system, or at least the line from Salonica to Mitrovitza, if the pending negotiations terminate satisfactorily. The line from Belgrade to Salonica will thus be in the hands of two French enterprises that have more than one point in common.

When the decision as to the exploitant has been made, it will be necessary to wait still further, until European diplomacy acts in concert, for the opening of the Salonica line to take place, although the Constantinople line be unfinished. This will be contrary to the bases of the treaty of Berlin, but we doubt not that, in the presence of the interests at stake, a modification of former understandings will be made in this direction, and that, too, very soon.

Although, on account of the backwardness of Bulgaria, the Constantinople line is not finished, it is already possible to reach the Turkish capital without crossing the sea. The Servian railways carry passengers as far as to Bela Palanka, and will soon carry them to Pirot. From the latter point to Bellova the trip is made very easily and safely by stage—one night being spent at Sofia. Many persons are now taking this route, which is the one of the future. In fact, when it is finished, the old route through Varna will be entirely abandoned. The voyage through Bulgaria will have the advantage of reducing the length of the trip and of doing away with crossing the Black Sea, and finally the traveler will not have to leave the car that he entered at Calais until he reaches Constantinople.

From a commercial and industrial point of view, the Bulgarian roads, connected on the two sides, will likewise have great importance. In fact, up till now, Bulgaria has been especially supplied by the ports of the Danube, and in particular by Lom-Palanka. To reach this point, French products, shipped from Marseilles by boat, cannot get beyond Galatz on the Danube until they have been transferred at this point to a boat belonging to the Danubian company, which carries them to the Bulgarian port for which they are destined. This is likewise the route followed by many products for Servia. From the Bulgarian ports, goods are distributed by wagons in the center of the country.

Despite the transfer at Galatz, this route, on account of its relative cheapness, is more followed than the one from Constantinople to Bellova. The products reaching this point by rail are distributed through the country by wagons.

As a consequence of the completion of the Servian roads, a new route is opened to the products of Central Europe. Numerous goods coming from Austria are already traversing Servia by rail as far as to Pirot. It is from this point that now start most of the wagons that have abandoned Lom-Palanka.

When the Vrania-Uskup section is opened, French products will be able to go from Salonica, through Vrania and Nich, to Pirot, and compete at this point with Austrian goods. Finally, when the Bulgarian roads are finished, foreign products will be carried by rail to the center of the country. French commerce and manufactures will have to compete at Sofia, as in Macedonia and Servia, with the English, who have large houses at Salonica—branches of the large establishments of the metropolis.

NEW RAILROADS IN EASTERN EUROPE.

As regards Servia, she, like Bulgaria, will enjoy the benefits of the large amount of travel of voyagers from Central and Western Europe toward the East. On another hand, she will no longer be a tributary of Austria, which is inundating her with its products.

The route from Galatz, mentioned above, has never been much followed, French commerce preferring that of Marseilles, Fiume, Sissek, and thence by boat to the Servian port of destination. This route, it is true, necessitates two transshipments and a trip of 120 miles by rail from Fiume to Sissek.

The true road hereafter will be that of Salonica, whence goods can go by rail to their destination. Among products capable of finding a ready market in Servia, we may mention fabrics, paper, groceries, and Parisian articles properly so called.

As regards Servian products capable of being exported, may be mentioned in the first class woods, cereals, and wines.

Finally, the large industries which are at present entirely wanting in Servia will soon be established.

There may be established there, with success, iron manufactories, foundries, sawmills, tanneries, paper mills, etc. To this latter point we would call the special attention of engineers and manufacturers.—*Annales Industrielles.*

A REPORT based upon an inspection of 1,214 factories in 125 different branches of work in Russia, states that the hours of labor there vary from six to twenty, and that in one or two special instances workmen were compelled to labor twenty-four hours uninterruptedly. These differences are purely arbitrary and not controlled by the kind of the work. In the same district in the same sort of work, there is sometimes a difference of eleven hours in the amount of work required in a day in the different factories.

SIBLEY COLLEGE LECTURES.—1887-88.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

I.—THE GENERATION OF STEAM.

By GEORGE H. BABCOCK, of N. Y. City.

THE making of steam by boiling water must have been discovered soon after the application of fire to man's uses. In fact, nature herself has been making steam since the earliest days in a manner quite suggestive to the observer. The boiling springs of Germany, Texas, and other places, and the geysers of Iceland, California, and the Yellowstone Valley, were doubtless carrying on the production of steam in great quantities long before man made his first kettle. So the subject we are to talk about on this occasion is not a new one. Nor do I suppose that I shall be able to say much on the subject which will be new to you. If, however, I am able to place a little knowledge derived from long experience into a concrete form for your use, I shall have fulfilled my object in coming before you.

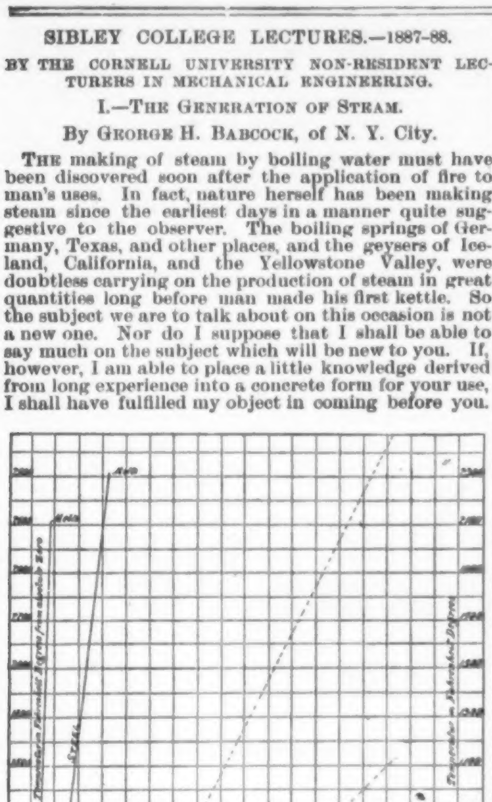


FIG. 1.

You are all well aware that what chemists designate as H O exists in three states or conditions—ice, water, and steam; that the only difference between these states or conditions is in the presence or absence of a quantity of energy exhibited partly in the form of heat and partly in molecular activity, which, for want of a better name, we are accustomed to call "latent heat;" and that to transform it from one state to another we have only to supply or extract heat. For instance, if we take a quantity of ice, say one pound, at absolute zero* and supply heat, the first effect is to raise its temperature until it arrives at a point 492 Fahrenheit degrees above the starting point. Here it stops growing warmer, though we keep on adding heat. It, however, changes from ice to water, and when we have added sufficient heat to have made it, had it remained ice, 283° hotter, or a temperature of 315° by Fahrenheit's thermometer, it has all become water, at the same temperature at which it commenced to change, namely, 492° above absolute zero or 32° by Fahrenheit's scale. Let us still continue to add heat, and it will now grow warmer again, though at a slower rate—that is, it now takes about double the quantity of heat to raise the pound one degree that it did before—until it reaches a temperature of 212° Fahrenheit or 672° absolute (assuming that we are at the level of the sea). Here we find another critical point. However much more heat we may apply, the water, as water, at that pressure, cannot be heated any hotter, but changes on the addition of heat to steam; and it is not until we have added heat enough to have raised the temperature of the water 966,° or to 1,178° by Fahrenheit's thermometer (presuming for the moment that its specific heat has not changed since it became water), that it has all become steam, which steam, nevertheless, is at the temperature of 212°, at which the water began to change. Thus over four-fifths of the heat which has been added to the water has disappeared or become insensible in the steam to any of our instruments.

It follows that if we could reduce steam at atmospheric pressure to water, without loss of heat, the heat stored within it would cause the water to be red hot; and if we could further change it to a solid, like ice, without loss of heat, the solid would be white hot or hotter than melted steel—it being assumed, of course, that the specific heat of the water and ice remain normal, or the same as they respectively are at the freezing point.

After steam has been formed, a further addition of heat increases the temperature again at a much faster ratio to the quantity of heat added, which ratio also varies according as we maintain a constant pressure or a constant volume; and we are not aware that any other critical point exists where this will cease to be the fact until we arrive at that very high temperature, known as the point of dissociation, at which it becomes resolved into its original gases.

* 460° below the zero of Fahrenheit. This is the nearest approximation in whole degrees to the latest determinations of the absolute zero of temperature.

The heat which has been absorbed by our pound of water to convert it into a pound of steam at atmospheric pressure is sufficient to have melted three pounds of steel or thirteen pounds of gold. This has been transformed into something besides heat; stored up to reappear as heat when the process is reversed. That condition is what we are pleased to call latent heat, and in it resides mainly the ability of the steam to do work.

The diagram, Fig. 1, shows graphically the relation of heat to temperature, the horizontal scale being quantity of heat in British thermal units, and the vertical temperature in Fahrenheit degrees, both reckoned from absolute zero and by the usual scale. The dotted lines for ice and water show the temperature which would have been obtained if the conditions had not changed. The lines marked "gold" and "steel" show their relation to heat and temperature and their melting points. All the inclined lines would be slightly curved if attention had been paid to the changing specific heat, but the curvature would be small. It is worth noting that, with one or two exceptions, the curves of all substances lie between the vertical and that for water.

In order to generate steam, then, only two steps are required: First, procure the heat, and, second, transfer it to the water. Now, you have it laid down as an axiom that when a body has been transferred or transformed from one place or state into another, the same work has been done and the same energy expended, whatever may have been the intermediate steps or conditions, or whatever the apparatus. Therefore, when a given quantity of water at a given temperature has been made into steam at a given temperature, a certain definite work has been done, and a certain amount of energy expended, from whatever the heat may have been obtained, or whatever boiler may have been employed for the purpose.

A pound of coal or any other fuel has a definite heat-producing capacity, and is capable of evaporating a definite quantity of water under given conditions. That is the limit beyond which even perfection cannot go, and yet I have known, and doubtless you have heard of, cases where inventors have claimed, and so-called engineers have certified to, much higher results.

THE FURNACE.

The first step in generating steam is in burning the fuel to the best advantage. A pound of carbon will generate 14,500 British thermal units during combustion into carbonic dioxide, and this will be the same, whatever the temperature or the rapidity at which the combustion may take place. If possible, we might oxidize it at as slow a rate as that with which iron rusts or wood rots in the open air, or we might burn it with the rapidity of gunpowder, a ton in a second, yet the total heat generated would be precisely the same. Again, we may keep the temperature down to the lowest point at which combustion can take place, by bringing large bodies of air in contact with it, or otherwise, or we may supply it with just the right quantity of pure oxygen, and burn it at a temperature approaching that of dissociation, and still the heat units given off will be neither more nor less. It follows, therefore, that great latitude in the manner or rapidity of combustion may be taken without affecting the quantity of heat generated.

But in practice it is found that other considerations limit this latitude, and that there are certain conditions necessary in order to get the most *available* heat from a pound of coal. There are three ways, and only three, in which the heat developed by the combustion of coal in a steam boiler furnace may be expended.

First, and principally, it should be conveyed to the water in the boiler, and be utilized in the production of steam. To be perfect, a boiler should so utilize all the heat of combustion, but there are no perfect boilers.

Second.—A portion of the heat of combustion is conveyed up the chimney in the waste gases.

Third.—Another portion is dissipated by radiation from the sides of the furnace. In a *stove* the heat is all used in these latter two ways, either it goes off through the chimney or is radiated into the surrounding space. It is one of the principal problems of boiler engineering to render the amount of heat thus lost as small as possible.

The heat escaping up the chimney is in proportion to the weight of the gases—their composition being substantially the same—and the difference between their temperature and that of the air and coal before it entered the fire. The weight of the gases cannot be brought, in practice, below that of the coal and the quantity of atmospheric air required for its combustion, but it may be and usually is made very much greater than this, by the admission of unnecessary air, and also by the admission of steam or water to the furnace, the latter being converted into steam, and swelling the volume of the products of combustion.

It is evident that the temperature of the escaping gases cannot be brought below that of the absorbing surfaces, while it may be much greater even to that of the fire. This is supposing that all of the escaping gases have passed through the fire. In case air is allowed to leak into the flues, and mingle with the

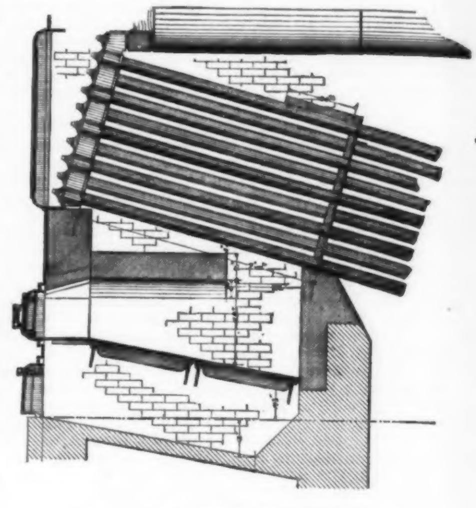


FIG. 3.—FOR BITUMINOUS COAL.

gases after they have left the heating surfaces, the temperature may be brought down to almost any point above that of the atmosphere, but without any reduction in the amount of heat wasted. It is in this way that those low chimney temperatures are sometimes attained which pass for proof of economy with the unobserving. All surplus air admitted to the fire, or to the gases before they leave the heating surfaces, increases the losses.

The loss from radiation is in proportion to the amount of surface, its nature, its temperature, and the time it is exposed. This loss can be almost entirely eliminated by thick walls and a smooth white or polished surface, but its amount is ordinarily so small that these extraordinary precautions do not pay in practice.

We are now prepared to see why and how the temperature and the rapidity of combustion in the boiler furnace affect the economy, and that though the amount of heat developed may be the same, the heat available for the generation of steam may be much less with one rate or temperature of combustion than another.

Assuming that there is no air passing up the chimney other than that which has passed through the fire, the higher the temperature of the fire and the lower that of the escaping gases the better the economy, for the losses by the chimney gases will bear the same proportion to the heat generated by the combustion as the temperature of those gases bears to the temperature of

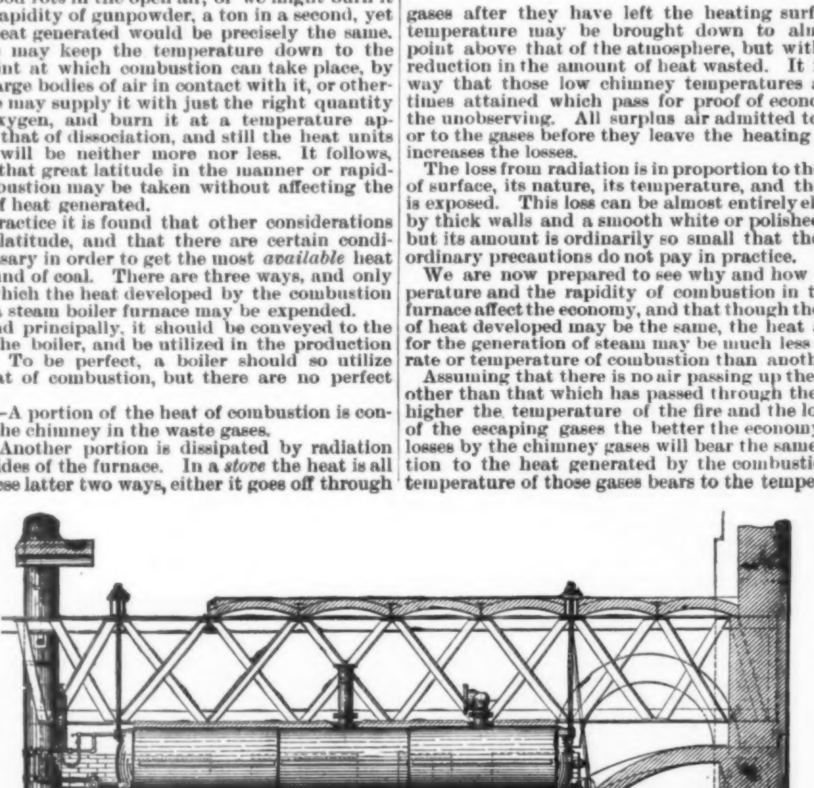


FIG. 2.—FOR ANTHRACITE COAL.

the fire. That is to say, if the temperature of the fire is 2,500° and that of the chimney gases 500° above that of the atmosphere, the loss by the chimney will be $\frac{500}{2500}$ = 20 per cent. Therefore as the escaping gases cannot be brought below the temperature of the absorbing surface, which is practically a fixed quantity, the temperature of the fire must be high in order to secure good economy.

The losses by radiation being practically proportioned to the time occupied, the more coal burned in a given furnace in a given time, the less will be the proportionate loss from that cause.

It therefore follows that we should burn our coal rapidly and at a high temperature, to secure the best available economy.

But practically there are limiting conditions in both these directions. In the line of the temperature of fire there are two such which act before the highest possible temperature of combustion can be reached. One is the ability of the furnace to stand the heat without melting. It is not an uncommon thing to see fire bricks melt and run down like metal, where a high temperature is attained. Another is the character of the fuel. Many kinds of coal melt and "clinker" at a moderate heat, and it is necessary in using such coal to burn it at a comparatively low temperature.

In the line of rapidity of combustion, the limiting condition is principally the amount of draught attainable. You will hear many firemen and some of the older class of engineers say that the way to secure economy is to burn your coal at a slow rate of combustion. This notion has arisen mainly from the practice of using a large grate surface in proportion to the heating surface of the boiler, so that in order not to supply more heat than the boiler was adapted to absorb, with economy, it became necessary to burn the coal at a slow rate per square foot of grate. But practice has shown that in such cases a reduction of grate area, with a corresponding increase in the rate of combustion—so that the same amount of coal was burned as before—has resulted in marked economy. For the same cause an unreasonable prejudice has arisen against the employment of a blast, as with a blower. The fact is that in most cases where the same amount of coal is burned in a given time under a given boiler, the use of a blower will increase the economy.

I remember an instance where a certain factory had been enlarged so greatly beyond the original intentions that the chimney proved too small, and complaint was made that they could not make steam enough with the boilers they had, and it was useless to add more, as the chimney already had more than it could do. A blower was recommended, but the owner said that that would ruin him, as it would take so much more coal to do the work. He was, however, with many misgivings, induced to make the trial, when; to his surprise and delight, he had all the steam he needed, with no increase in the amount of coal burned.

The explanation of this fact leads us to another practical point about which there is much misapprehension. That is the proper thickness of the fire. Some men will tell you that thin fires are best, and others that they must be carried very thick. As a consequence, you will see variations all the way between three inches and twenty-four. As I have already told you, more air than sufficient for combustion passing through the fire lowers the temperature and increases the waste. Thin fires admit too much air, while too thick fires admit too little, which is perhaps even worse than too much. In the case referred to the fires had to be carried very thin in order that the weak chimney draught might burn the coal, and so, doubtless, much too much air was used. With the fan blast the fires could be carried thicker, and a higher temperature attained. Hence greater economy.

And here we may consider the favorite fallacy of admitting "air to burn smoke." This has been experimented with since the days of Thompson, in 1796, by very many, and has always been found to be a detriment in the hands of ordinary firemen. With an intricate automatic apparatus, which gradually reduced the quantity of air thus admitted, for a short time after firing, and shut it off entirely in two or three minutes, Prideaux succeeded in gaining an economy when using the highly bituminous coal of England and Scotland.

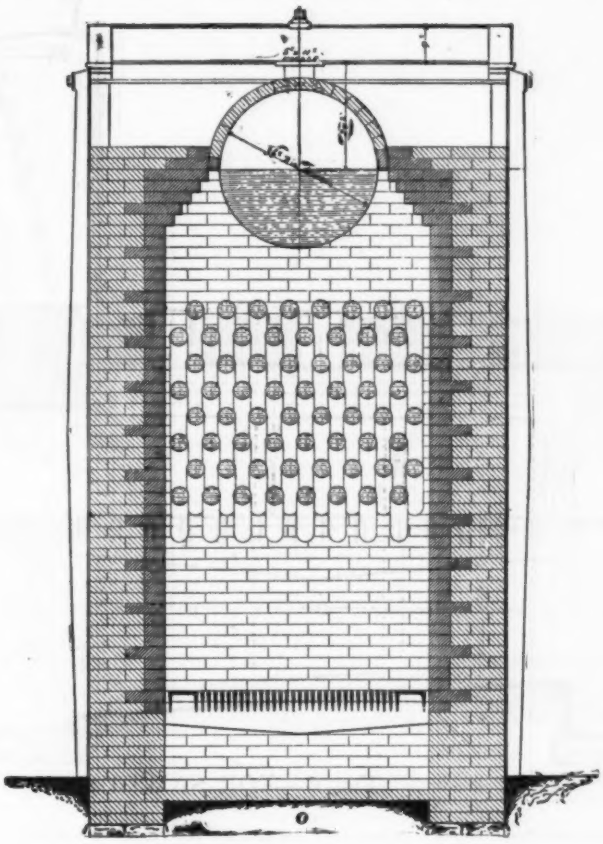


FIG. 5.—FOR WOOD.

But the plan did not recommend itself largely in practice. A precisely similar device, without the refinements which made Prideaux's economical, has been much boomed in this country, and by judicious but unprincipled advertising and pushing has been largely sold. It has actually been put in for burning anthracite, where even the poor excuse for "burning smoke" cannot be pleaded.

You may set it down as a rule that when coal is properly fired all the air required, and generally more than enough, will pass through the coal on the grate bars, and all air elsewhere admitted is an addition to the waste.

The kind of furnace required will depend upon the kind of fuel to be burned. The furnace which is best for one kind may be the worst for another.

A variety of furnaces for different fuels are shown by Figs. 2 to 14.

Fig. 2 shows the furnace usually employed for anthracite coal, being simply a plain furnace with grate bars, the spaces between the bars varying from one-eighth of an inch to an inch, according to the size of the coal. This figure is interesting as being a correct drawing of one of the boilers in the New York Steam Company's Station B, which is doubtless the largest boiler house in the world, containing at the present time 12,000 h. p. of boilers under one roof, which will probably be increased another season to 20,000 h. p.

Fig. 3 shows the construction of a furnace adapted for burning bituminous coal. It differs from that for anthracite in having a reverberatory arch thrown over

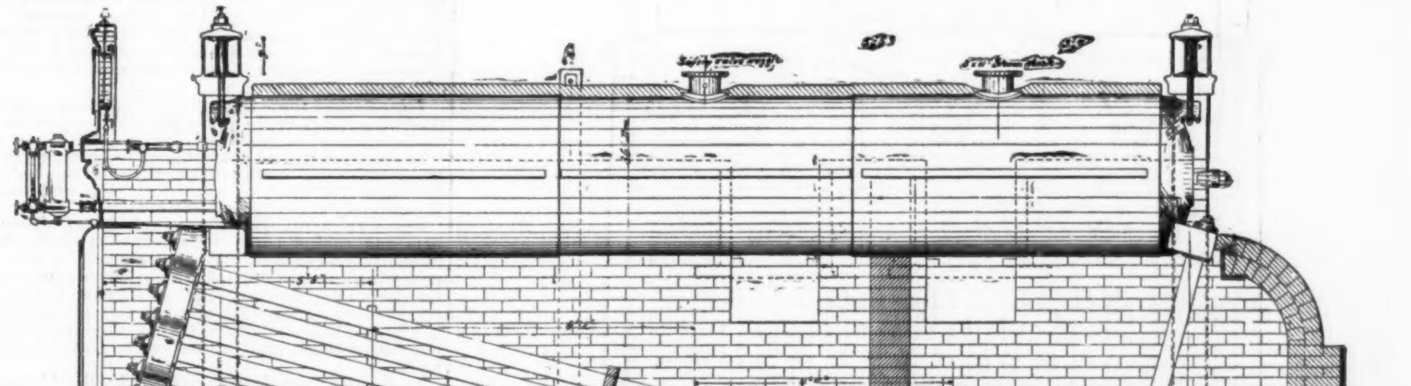


FIG. 4.—FOR WOOD.

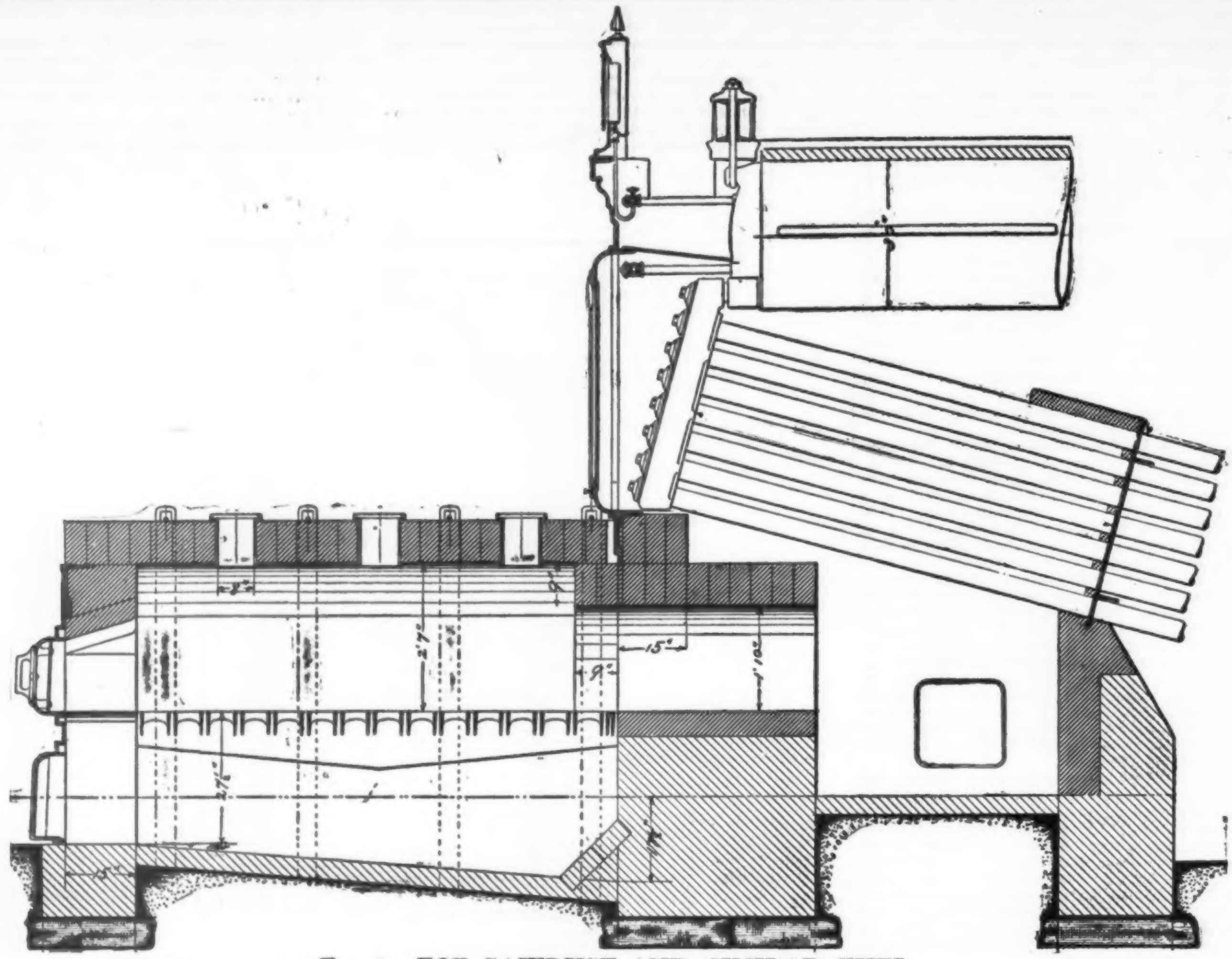


FIG. 6.—FOR SAWDUST AND SIMILAR FUEL.

the grate bars for a portion of their length. A furnace of this character, particularly if the coal is fired mainly in front and pushed back after the volatile gases have been driven out of it, will burn highly bituminous coal without any smoke, and with good economy. The reverberatory arch is an important element in every furnace for burning this kind of coal.

Figs. 4 and 5 show a furnace adapted to burning wood. You will notice that there is a space along each side of the furnace and at the end, in which there are no air spaces through the grate bars. The furnace is also high and provided with a double set of doors. The object of the blank space around the sides and ends of the furnace is to prevent a rush of cold air around the ends and side of the wood, all the air that passes through the grate bars being compelled to pass through the body of the wood, where it will assist in combustion.

Figs. 6 and 7 represent a furnace adapted to burn sawdust and similar fuel. In this furnace a reverberatory oven is provided outside of the boiler for the reception and burning of the fuel, which is fed generally by automatic arrangements through the openings in the roof of the furnace. It is necessary, also, for this fuel to use a larger area of grate than is requisite for coal in a given sized boiler.

(*To be continued.*)

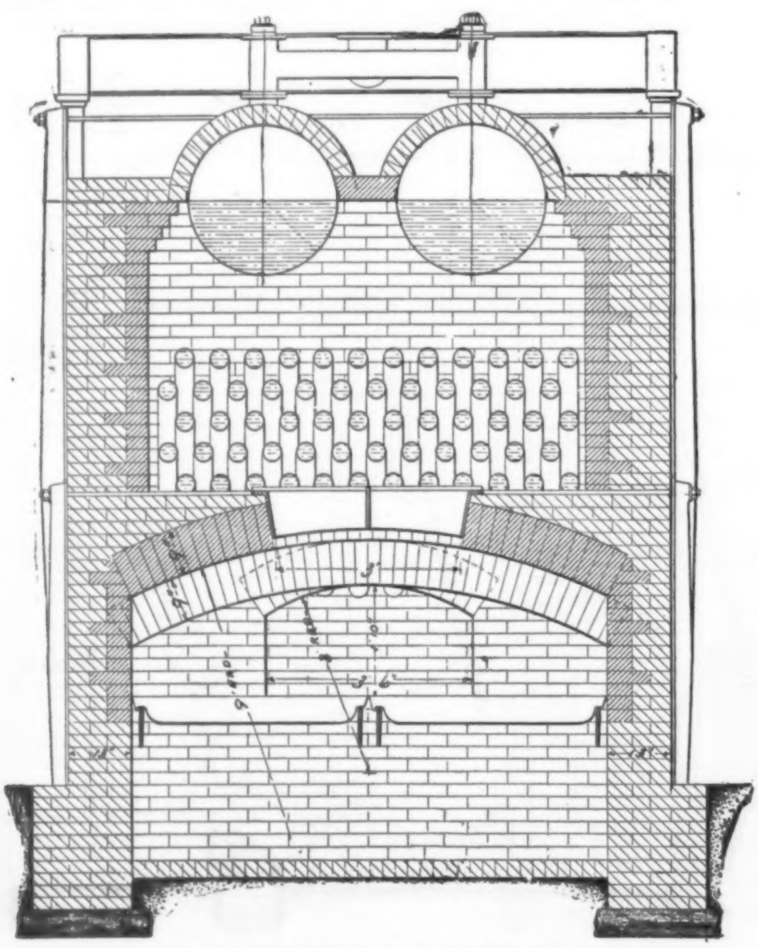


FIG. 7.—FOR SAWDUST AND SIMILAR FUEL.

MODERN ICE YACHTS.*

By GEO. W. POLK.

THE ice yacht of to-day is quite a different craft from those which had been in use up to the year 1880.

Previous to that time they had been constructed of, say, five pieces of timber, viz., keelson, bowsprit, runner plank, and two side rails, the latter joined at the stern, and extending forward to and holding the runner plank in position; the box being formed by boarding over for a part of the way from the stern forward the space between the side rails.

The drawings which accompany this will give a comprehensive idea of what the boats now in use are, and their superiority in speed has been so far demonstrated that none of the old style boats are now built.

Plate 1 gives in detail the parts, Fig. 1 representing thickness of keelson and bowsprit, while Fig. 2 shows the method of joining these timbers together. The pieces are laid together with glue, and screw bolts put through from bottom of keelson, except toward the after end of bowsprit, where it diminishes in width, ordinary screws are used.

Figs. 3 and 4 show the runner plank with chucks for the runners attached, details of which are shown more especially in Figs. 21 and 22.

In Fig. 4, it will be noticed that the runner plank is thickest in the center, diminishing to the ends, and having a "crown" or arch both top and bottom, though only slightly so on the bottom.

Fig. 5 shows method of connecting the center timbers and runner plank together; *a* is center timber (bowsprit and keelson), *b* runner plank, *c* iron gammon strap (see also Fig. 6), which passes over the center timber and down through the plank, having nuts on the bottom, screwing up to an iron plate, as shown in Fig. 7. The object of this strap is of course to prevent the runner plank slipping an end when the boat is in motion.

In this it is very largely assisted by the ½ inch wire rope shrouds, *d*, *d*, *d*, *d*. Those forward of the plank (bowsprit shrouds) have an eye turned in each end and are fastened to bowsprit by means of bolts, *e*, *e*, which pass down through the cap and bowsprit, the stick being scored out to receive shroud, as shown at *a*, *a*, Fig. 2. The after ends are secured to runner plank by means of iron plates, *f f* (see also Figs. 12 and 13), the ends or jaws of same being turned slightly to lead fair with shroud, whose end passes between the jaws, and is held by bolt as shown.

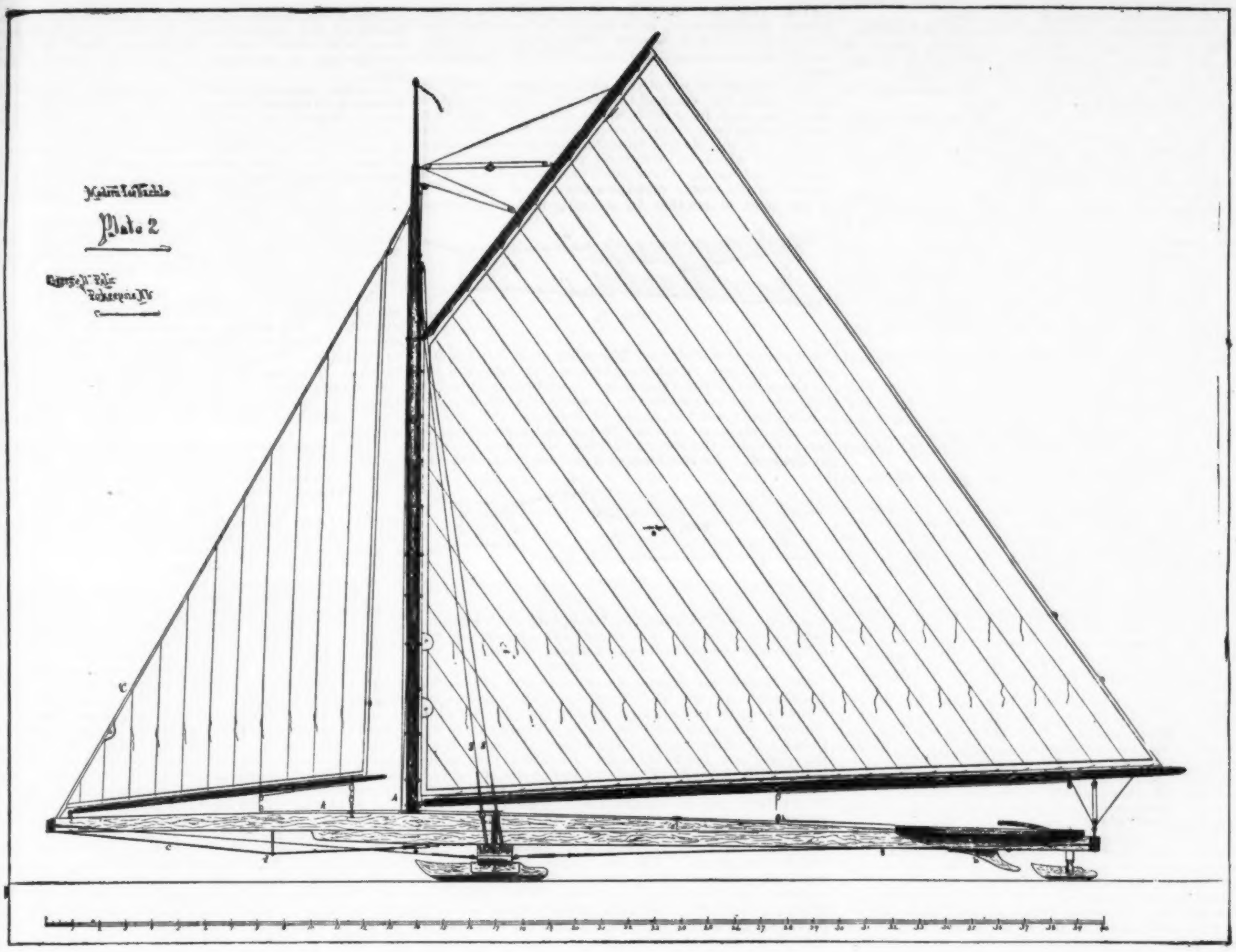
The shrouds abaft the plank have turnbuckles, *g g*, on their forward end, and are secured to keelson at *h h* by bolts in same way as at bowsprit end, except that the bolts are continued around in one piece, and made to serve as main sheet traveler also, as shown by Fig. 14.

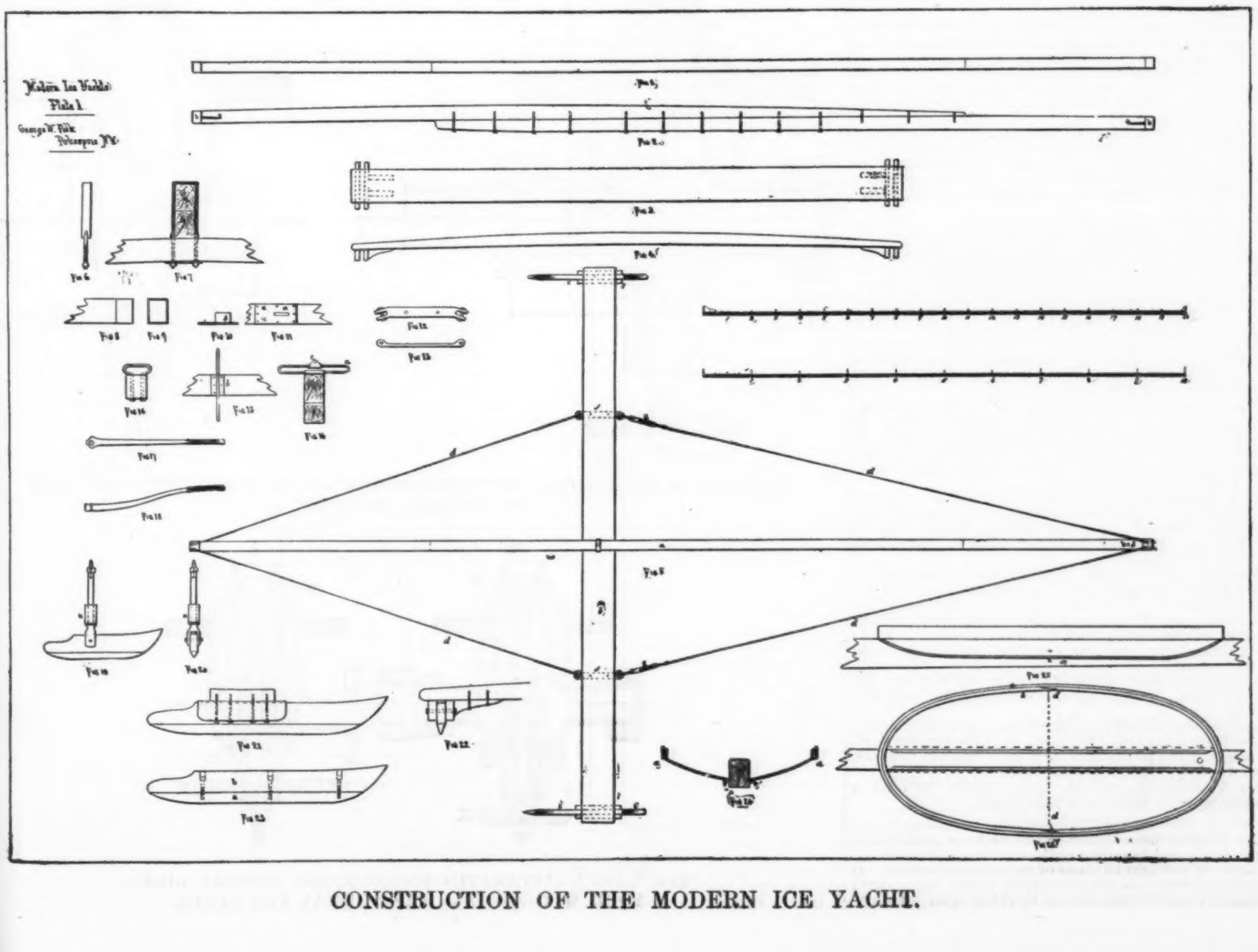
The purpose of turnbuckles, *g g*, is to so adjust the runner plank that the runners, *i i* (which have previously been put in perfect alignment with each other), may move perfectly parallel to a line drawn in the direction in which boat is headed.

It will be readily seen that if they are not thus parallel, the runners must scrape, or shove sideways, just to the extent that they are out of "line."

This adjusting, or "horning," is done by means of a long batten placed against rudder post at *k*, then to a spot on edge of runner plank set off an equal distance on each side of the center, or in the angle made by the

* For illustrations and description of the former method of constructing ice yachts, see SCIENTIFIC AMERICAN SUPPLEMENT, No. 1, Jan. 1, 1876, and No. 61, March 3, 1877.





CONSTRUCTION OF THE MODERN ICE YACHT.

plank and chucks at $l\ l$. When the distance from rudder post to the points (by use of turnbuckles) is made equal, the runners are said to be in "line."

The bands or caps on ends of bowsprit and keelson, $b\ b$, Fig. 2 (also Figs. 8 and 9), are simply pieces of band iron, made to required size, and a piece of mahogany or other wood fitted in ends for a finish.

The "box," or resting place for the helmsman, is shaped as shown by Figs. 24, 25, and 26.

Fig. 24 is a cross section taken at the greatest width, or d, Fig. 26. The bottom is screwed fast to sides, as at $d\ d$, and held in position on the keelson by strips, $b\ b$ (see also d, Fig. 25), which are screwed both into the keelson and bottom of box.

In Fig. 26, the sides, b, are of oak in two pieces, steamed and bent to shape, then scarfed together at d. The pieces, c, are sprung around afterward to form a finish, being usually of some fine wood.

Fig. 23 shows manner in which the chilled iron shoe of runner, a, is secured to the wood, b, by bolts having a thread which corresponds to one tapped in the shoe.

Fig. 19 shows rudder and iron rudder stock, a in Figs. 19 and 20 being a piece of rubber car spring.

Fig. 20 is a fore and aft view of the rudder stock, and also cross section of rudder.

Figs. 17 and 18 are views of the tiller, which is forged out of iron, and solid, usually nickel-plated.

Figs. 15 and 16 represent the jib traveler. The rod, a, Fig. 16, is welded to plate, b, Fig 15; the slide, c, Fig. 16, being put on the rod before welding—the whole screwed fast to bowsprit at point, a, plate 2.

Fig 14 is main sheet traveler, shown in its proper position on plate 2.

Figs. 12 and 13 represent the iron plates shown at $f\ f$, Fig. 5.

Figs. 10 and 11 show the mast step. It is an iron plate, a, Fig. 11, as wide as thickness of keelson, having a piece of iron about 3½ in. long, 3 in. wide or high, and ¾ in. thick, welded to it (b, Fig. 10), the foot of mast being mortised out to receive it. $c\ c$, Fig. 11, are fair-leaders for use as explained hereafter.

Basswood is generally used for the center timbers and runner plank, and its lightness as well as stiffness makes it very desirable for the purpose. It is however quite difficult to get of the required length and size, and is usually gotten out especially for the purpose.

Butternut has sometimes been employed, but is also difficult to get.

Many kinds of wood have been used for runner planks, but with the great length of to-day (most of the larger boats tracking 26 ft between runners, and some even more) it is rather a necessity to use lighter timber, and make a saving in weight.

On plate 1, the smaller scale is used for Figs. 1, 2, 3, 4, 5, and the larger one for remaining figures.

Plate 2 represents the yacht in elevation, showing also spar and sail plans.

a shows position of jib traveler, previously described. b is a figure not heretofore mentioned. It is simply a piece of oak 2 or 2½ in. thick, and of the shape shown; its purpose is to run the rudder out of a crack or hole in the ice, in case it should drop through.

The jib stay, $c\ c$, passes down through the bowsprit, under the martingale, d, and is set up by a turnbuckle, e, on under side of keelson; this done to prevent the bowsprit pulling up, allowing the mast to drop back, and causing the sail to "bag."

Sometimes, and in addition, a bobstay is run from the bowsprit end, passing over martingale, d, under runner plank (and setting up as the jib stay does) nearly or quite to the box, say at f.

The mast is held in position by the ½ inch wire rope shrouds, $g\ g$, which are set up by deadeyes and rope lanyards as shown.

The bolts which hold lower deadeyes to the runner plank pass through the plank, and also through the iron plates, $f\ f$ (Fig. 5, plate 1), screwing up to the plates by nuts on under side.

The sails for a boat of this size would be made of about No. 6 duck. Their area in this case is 570 sq. ft. giving 26 sq. ft. of canvas to every foot in length between runners, which is about the usual proportion, some running a little over, and some under these figures.

The center of effort of sails is situated at a point in the mainsail indicated by a dot with circle about it.

As an ice yacht (from the greater width between runners now usually given them) rarely departs from an upright position, the center of effort remains a permanent point, or nearly so, and should properly come over or a little abaft the center of lateral resistance, which is virtually the center of runner plank.

This would insure getting the boat away from the wind in turning windward stakeboat, which, when a race is sailed in heavy weather, many of them experience considerable difficulty in doing.

But to bring the runner plank back to the point indicated would, by the pressure of wind (which is always forward and tending to depress) and weight of the mast, cause the boat to "tip up," lifting the rudder clear of the ice, and, of course, causing the helmsman to lose control of her.

The experiment yet remains to be tried of bringing the runner plank back but at same time extending the keelson far enough out so that the box shall be clear of the sail and give weight enough to counterbalance that forward of the plank.

The peak halyards pass through a hole which is put fore and aft through the foot of mast, and lead into the box, belaying to a cleat convenient to helmsman, while the throat and jib halyards pass through fair leaders, mentioned previously, and shown at $c\ c$ (Fig. 11, plate 1), belaying to a cleat on bowsprit midway between box and mast.

The jib and main sheets lead into the box, the jib sheet passing through mast as described for peak halyards.

It is rather difficult to estimate the cost of such a craft as has been described, but to any one who does the work themselves, the probable cost of sails, rigging, runners, etc., would not exceed $300 or $350.

By a change in scale the plans can be used for a proportionately larger or smaller boat.

AN English lock maker claims to have perfected a door, to be used in public buildings, that will lessen the chances of accident in times of panic or real danger. It is opened from the outside only by a key, but a slight pressure from within causes it to swing open outward.

A SIMPLE THERMOSCOPE.

FOR a year past, there has existed in Berlin a disinfecting establishment, in which all objects that have been in contact with persons suffering from a contagious disease are submitted to the action of superheated steam.

The disinfection is not regarded as perfect until the entire mass has reached the elevated temperature of the steam, and, in order to make sure that such temperature has been everywhere reached, Mr. Merke, the director of the Moabit Hospital, has devised a simple apparatus, which he introduces into the interior of the mass to be treated. It consists of two pieces of wood jointed at the center, and the ends, $a\ a$, of which (Fig. 1) are held in contact by a spring and are provided

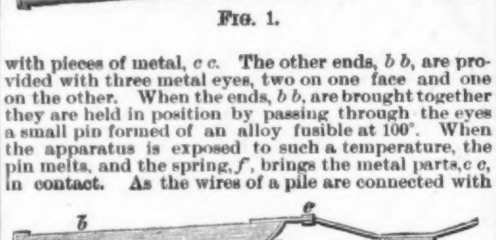


FIG. 1.

with pieces of metal, $c\ c$. The other ends, $b\ b$, are provided with three metal eyes, two on one face and one on the other. When the ends, $b\ b$, are brought together they are held in position by passing through the eyes a small pin formed of an alloy fusible at 100°. When the apparatus is exposed to such a temperature, the pin melts, and the spring, f, brings the metal parts, $c\ c$, in contact. As the wires of a pile are connected with

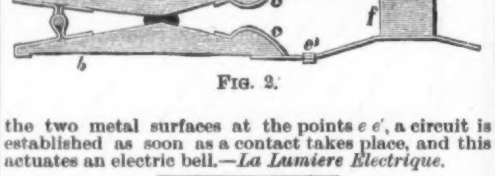


FIG. 2.

the two metal surfaces at the points $e\ e'$, a circuit is established as soon as a contact takes place, and this actuates an electric bell.—*La Lumiere Electrique.*

AN IMPROVED EARTH PLATE.—In the *Electrotech. Zeitschrift* for October, Professor Dorn proposes a form of earth plate which should be valuable to all observers of earth currents if, as is claimed for it, it reduces polarization to a minimum. It consists of a flat open box, made of wood or cement, and coated inside with asphalt. This is placed at the bottom of a hole in the ground. An amalgamated zinc plate lies flat in the box, and an insulated wire leads from it to the surface. Care must of course be taken that the joint is well covered, so that nothing but zinc is in contact with soil. An earthenware pipe stands on the zinc and rises to the surface. The box is then tightly rammed with clay, soaked with concentrated zinc sulphate solution, and the hole filled up. Solid sulphate is dropped down the tube and solution poured after it. A little fresh sulphate from time to time will keep the plate in order.

USE OF LIQUID FUEL ON TORPEDO BOATS.

THE Naval Board, after trying our atomizers on the boiler of the torpedo boat Chevrette, at Cherbourg, along with other similar apparatus, asked us a few months ago to elaborate a definitive device of this kind.

Our first apparatus, which was designed for heating boilers with natural draught, consists of a conical bronze box, A (Figs. 1 and 2), which the liquid hydrocarburet enters through the tubulure, B. The outlet of this box is closed by a rod, C, which, maneuvered by means of a hand wheel, leaves between it and the sides of the cone an annular space whose width varies from 0 to 2 mm. It is through this space that the naphtha is admitted into the fire box.

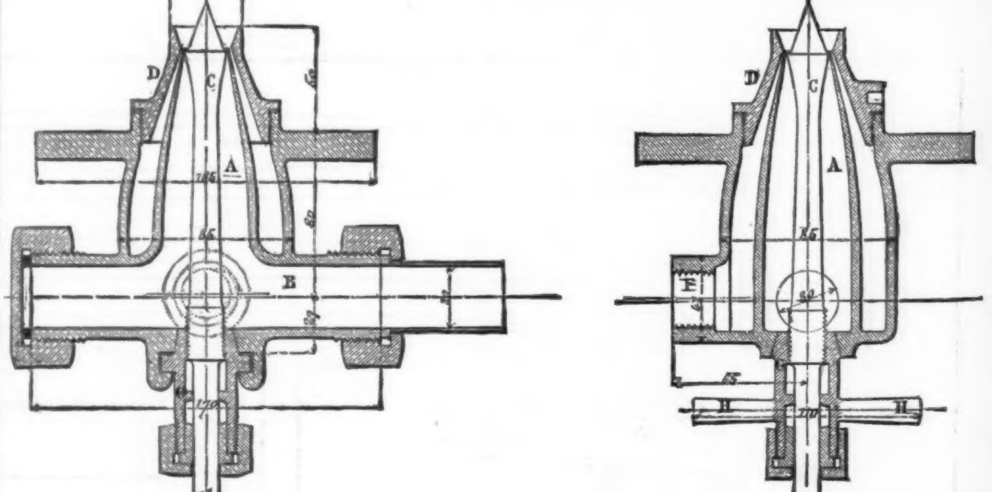
The steam, which enters through the tubulure, F, surrounds the box, A, and warms its contents, and then flows between the cones, A and D, surrounds the naphtha, converts it into a fine spray, and projects it with force into the fire box.

The naphtha thus reduced takes fire upon contact with an ignited body, and burns without smoke. The activity of the furnace is regulated by the rod, C, which, on being moved backward or forward, increases or diminishes the quantity of hydrocarburet that is flowing. The use of two apparatus, mounted alongside of each other, renders it very easy to regulate the heat, since one of the two can be at once extinguished, or be lighted by opening the cock that lets in the naphtha.

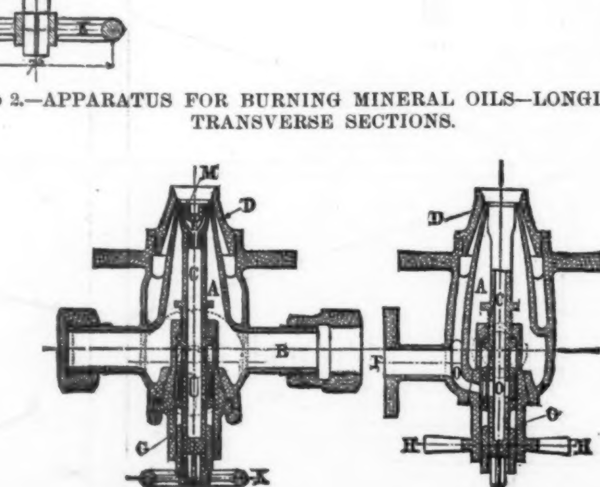
These apparatus work well, and through a simple maneuver of the central rod can be made to burn from 20 to 175 pounds of naphtha per hour. Two apparatus, then, burning together 350 pounds of naphtha, would be able to evaporate at the rate of 6½ quarts per pound of fuel—$350 \times 6\frac{1}{2} = 2,275$ quarts (569 gallons) of water per hour; and, admitting that three quarts per square foot of heating surface are evaporated (which is nearly the limit with a natural draught), the apparatus would be adapted to a boiler having a heating surface of 1,200 square feet. But in the boiler of a torpedo boat it is necessary to go much beyond this, by having recourse to a forced draught. Instead of burning 350 pounds of naphtha in the furnace, it is necessary to burn double that, or even more if possible.

In order to solve this question, it would seem sufficient at first sight to increase the diameters of the apparatus, but such is not the case. In fact, if we do this, the fuel flows in greater abundance, but is not perfectly atomized, the combustion is incomplete, and a thick black smoke is produced. To overcome these drawbacks it is absolutely necessary to have recourse to an energetic atomizing of the liquid. This is what led us to add a second steam conduit to the interior of the apparatus. The naphtha is thus inclosed between two atomizing portions of steam, and none of its particles can escape the process.

The apparatus that fulfills these conditions (Figs. 3 and 4) consists, like the one just described, of a conical box, A, that the naphtha enters through the tubulure, B. The steam enters through the tubulure, F, and passing into the cone, D, surrounds the naphtha; and it likewise passes through the orifices, O, enters the rod, C, which is hollow, and meets the cone, M, which



FIGS. 1 AND 2.—APPARATUS FOR BURNING MINERAL OILS—LONGITUDINAL AND TRANSVERSE SECTIONS.



FIGS. 3 AND 4.—APPARATUS FOR BURNING MINERAL OILS—FORM WITH DOUBLE PASSAGEWAY FOR STEAM.

forces it to flow into the furnace in a conical form within the naphtha. This apparatus is regulated and taken apart like the preceding. It is capable of burning as many as 800 pounds of naphtha per hour, without the least sign of smoke.

The results of experiments with this apparatus show that vaporization therewith reaches limits that cannot be attained with coal.—*J. D'Allest, in Le Genie Civil (Abstract).*

THE NEW HEBRIDES.

A YEAR last June the French government, on the plea of protecting their subjects in the New Hebrides from massacre, and of inquiring into the circumstances under which two Frenchmen were murdered by the natives, dispatched a small force of troops to the islands, and established a military post. This decisive action caused some anxiety in England, and more so in Australia, where this step was regarded a breach of the treaty of 1848, and as a determination on the part of France to annex the islands for a convict station. Negotiations were speedily entered into between the British and French cabinets, which have eventually resulted in a new convention, which was signed in Paris recently. By this England consents to abrogate the treaty of 1847, which bound France not to intervene in the Raiatea Islands (Tahiti Archipelago), while France consents to withdraw her troops from the New Hebrides, the maintenance of order there being in future intrusted to the naval officers of the French and British squadrons in the Pacific, who are to act under certain rules. Our sketch is by Lieut. C. L. Ottley, R.N., and shows the volcanic island of Tanna. It is, and has been for many years, in a state of constant eruption, emitting a column of fire by night and of smoke by day. Such is the certainty with which this flame appears, that vessels in the vicinity are instructed by the sailing directions to look out for it just as they would do were it an ordinary light-house.—*The Graphic.*

A NATURAL LIGHTHOUSE—THE VOLCANIC ISLAND OF TANNA.

[SCIENCE.]

THE TRANSCONTINENTAL RAILROADS.

THE transcontinental railroads cross great plains, high mountains, lofty plateaus, and broad basins, and follow the courses of long rivers. Nowhere do we find objects of greater interest to the traveler, geographer, geologist, or the student of natural history than along these lines of travel. The rivers that rise on the eastern slope of the Rocky Mountains pursue an uninterrupted and peaceful course from the foot hills, across the great plains, to the valley of the Mississippi. The rivers that rise on the western slope encounter range after range of mountains, some higher than the Rockies, and find their way to the ocean over high falls, through deep canons, or by forcing a way through mountain ranges. Here is the longest persistent range of mountains in the world—broad plateaus elevated from 8,000 to 10,000 feet above the level of the sea. Here are deep basins, with mountains so closely surrounding them that the streams, unable to find a way to the ocean, sink into the desert. Here is the valley of the Colorado, running through canons 3,000 to 4,000 feet high, over 200 miles long, and so deep that in some places the sunlight never reaches the bottom.

The rain, instead of fertilizing the ground, washes from the rocks every particle of soil, and leaves the country a desolate wilderness, devoid of vegetable or animal life. Here are high snow mountains, and at their base deep valleys, sunk below the level of the ocean. There are mountains, more beautiful than Mont Blanc or the Matterhorn, rising directly from base to summit, 14,000 feet in height, with glaciers exceeding in extent and beauty any in Europe. From the far north to the extreme south are mines of gold, silver, and copper and vast deposits of coal, lead, and iron ore. Here the student of natural history finds fossils in endless variety and number, from the toothed bird to the miniature horse. As a compensation for the want of trees on the mountains, the largest and finest forest trees in the world are found at their base, on the Pacific coast. The millions of buffaloes which formerly roamed over the plains are all gone, but their places are supplied by countless herds of cattle and flocks of sheep. Such a land is worth visiting; and the description of the country through which the railroads run, and of the roads themselves, must be of interest.

The traveler from the Atlantic to the Pacific by either of the transcontinental railroads enters the great plains soon after crossing the 95th degree of longitude near Winnipeg on the north, Omaha and Kansas City in the middle latitudes, or San Antonio at the south.

Then commences the ascent, steadily continued until the top of the Rocky Mountains is reached. The land rises, at first slowly, then on steeper grades, and yet so gradually that the passenger on the Union Pacific reaches an elevation of one mile before he has seen the mountains or realizes that he has attained any considerable elevation. From the foot hills, over the mountains to the Pacific Ocean, each road follows a route having its own features, so striking and distinct that no general description is of any value. The chief objects of interest are the great plains, the Rocky Mountains, the deep basins, the ranges of mountains west of the Rockies, and the plateau of the Colorado River; while the railroads—the work of man—vie in interest with the natural wonders.

THE GREAT PLAINS.

Looking from Denver toward the west, or better yet, from almost any part of the great plains in Colorado within 50 miles of the Rocky Mountains, are seen the foot hills, then the mountains, rising higher and higher until lost in the distant snow caps. Looking toward the east are the green and grassy plains falling in gentle undulations, north, south, and east, as far as the eye can reach, and for hundreds of miles beyond. These are the great plains of America, bounded by the Rocky Mountains on the west, the Arctic Ocean on the north, the Gulf of Mexico on the south, the Missouri and Mississippi Rivers on the east. The great plains reach their culminating point between Denver and Colorado Springs—at the divide between the waters of the North Platte and Arkansas Rivers. From this elevation of 7,000 feet they slope northeasterly into Wyoming and Canada, toward the Arctic Ocean, easterly to the Missouri River, and southerly into New Mexico. The land, only fairly watered on the east, becomes arid toward the foot hills of the Rockies, and though rich and fertile, cannot be cultivated without irrigation. The rivers grow larger toward their sources, as the rainfall on the plains is insufficient to supply the loss by evaporation and irrigation; but there is no portion of these plains that deserves the name of desert, or that is comparable in degree of sterility with the canoned country west of the mountains. It is only a few years since it was called the "Desert of America," and it was then believed that the great plains were unfit for cultivation or habitation. Then they began to be used for pasturage of cattle. Now, by a judicious system of irrigation, larger crops of wheat and grain are grown than in the great prairie States, while the detritus from the irrigating water more than compensates for the exhaustion of the soil by the crops.

THE ROCKY MOUNTAINS.

These mountains rise in Alaska, on the Arctic Ocean, far to the north of Sitka, and attain their highest elevation—20,000 feet—in Mount St. Elias. They run through British Columbia, Idaho, Montana, Wyoming, and Colorado. They appear as high, level plateaus and spurs in New Mexico and Arizona, joining the Coast Range, to appear again as the Rocky Mountains or Cordilleras in Mexico, where they attain the height of 19,000 feet in Popocatapetl, passing thence through the isthmus of Central America into South America, where they form the backbone of that continent, terminating near the Antarctic Ocean at Cape Horn. Mount Brown and Mount Hooker, in British Columbia, rival Monte Rosa in height. The highest mass of these mountains is in Colorado, where there are nearly one hundred peaks 14,000 feet in height, none of which are 500 feet above or below that height. It is impossible to give definite boundaries to the Rocky Mountains, as they inclose many ranges and systems. Major Powell, of the Geological Survey, classes the Rocky Mountains into the park, the geyser, and the basin systems.

In the mountains and plateaus of these systems bare rocks are seen to an extent rarely found on the globe, and the region is largely destitute of soil and timber. In striking contrast to this destitution are the parks in Wyoming, Colorado, and New Mexico. The largest of these are the North, Middle, and South Parks of Colorado—elevated plains containing from 800 to 1,000 square miles, 9,000 to 10,000 feet above the sea level, surrounded by high mountains, with a fertile soil, furnishing fine pastures for cattle in summer, but with the warm season so short that wheat and grain do not ripen. In these mountains rise the great rivers of the world—the Missouri, Mississippi, the Columbia, and Colorado, in North America; and the Amazon and La Plata in South America.

The geyser system is in Wyoming. The mountains are not so high as in the other systems, but in their recesses lies the Yellowstone Park. Before the geysers of this park "all others in the world, even the celebrated ones of Iceland, sink into insignificance. This park seems to have been set aside by the Great Maker for the exhibition of the action of volcanic forces."

THE GREAT BASIN.

The Great Basin, so called because it has no drainage into the ocean, extends from the summit of the Rocky Mountains and the plains of the Colorado River west over one thousand miles, far into California, and from Oregon in the north over fifteen hundred miles south into Lower California, south of Los Angeles and San Diego. It includes the middle and western parts of Colorado, the whole of Utah and Nevada, and parts of Oregon and California.

Numerous short ranges run invariably north and south, with deep valleys between them. The greatest of the basins is that of Salt Lake, five hundred miles long and six hundred miles wide, between the Rocky and Sierra Nevada Mountains. Here rain scarcely falls, and the rivers which rise in the mountains surrounding it on every side are soon dried up, or, like the Carson and Humboldt, after running from 100 to 300 miles, sink into the desert and disappear. Large lakes are formed in the deeper valleys, but the water in them is salt. For hundreds of miles the traveler sees only alkali plains, breathes alkali dust, and drinks alkali water. Far to the southwest is Death Valley, over 150 feet below the level of the ocean, so called from the number of emigrants who lost their lives from hunger and thirst in sight of the snow mountains and close to the promised land. But as if to compensate for the desert of death, on the opposite side of the Sierras are the Yosemite and the trees of Calaveras. The mountain ranges west of the Rocky Mountains are popularly called the Cascade, Sierras, and Coast Range.

THE CASCADE MOUNTAINS.

The Cascade Mountains rise in the upper part of British Columbia, follow the coast line through British Columbia and Washington Territory, passing thence through Oregon, and die out in northern California, to be succeeded by the Coast Range. The snow line is reached at a lower elevation than in Switzerland, and, unlike the Alps, the great mountains rise directly from the sea 14,000, 15,000, and even 20,000 feet in height. From the sides of Mount St. Elias in Alaska—the highest mountain in America—vast glaciers run into the ocean, exceeding in grandeur and extent any found in Switzerland. Mount Baker and Mount Tacoma in Washington Territory, and Mount Hood in Oregon, radiant with eternal snow, are more beautiful than Mont Blanc or the Matterhorn; the glaciers on Mount Tacoma equal those of these mountains, while, to add to the sublimity of the scene, smoke is frequently seen rising from the craters of Mount St. Elias and Mount Adams.

There is probably no other country where, on the same parallel of latitude, and at the same elevation, there are such great differences in climate, soil, and vegetation as on the east and west sides of the Cascade Mountains. On the east are barren hills and plains, devoid of all vegetation save the sage brush and bunch grass; the climate is hot in summer, cold in winter, and dry as that of the Desert of Sahara. On the west side of the range, and not fifty miles away, the country is thickly studded with the finest of forest trees, abounding in vegetable life, with a continuous rainfall, the climate mild in winter and temperate in summer. On the foot hills and in the western valleys the deep green of the Douglas fir, extending for hundreds of miles, contrasts with the pure white of the snow. The only drawback is the thick clouds of smoke from burning forests, which usually darken the sun and hide the mountains from view for two or three months in the summer.

SIERRA NEVADA.

The Sierra Nevada range might be called a continuation of the Cascade Mountains; but those are of volcanic origin, and the Sierra Nevadas are granite, though traces of volcanic action are often found on the flanks and base. It commences at Mount Shasta, 14,400 feet high, and runs in a southerly direction to Tejon Pass, where it joins the Coast Range not far from Mount Whitney, the highest mountain in the United States south of Alaska. There are but few passes over these mountains, and the Pacific slope is very steep, the Central Pacific road descending 6,300 feet in 80 miles.

COAST RANGE.

This is a long range of sandstone mountains. Rising in Oregon, south of the Columbia River, it follows the coast through Oregon and California into Mexico, where it unites with the Rocky Mountain range proper. It is lower than the other ranges, attaining an elevation of 3,000 to 5,000 feet. At the foot of this range, far to the east, is the Willamette River in Oregon, the Sacramento and San Joaquin Rivers in California, with long narrow valleys unsurpassed in richness. On the western slope the rainfall is abundant, and the valley and foot hills are covered with a luxuriant growth of vegetation—the redwood, Douglas fir, and other members of the *Sequoia* family, more useful than the big trees, and in large groups scarcely less imposing.

The Coast and Cascade ranges run parallel with the coast; and the Fraser, Columbia, and other large rivers, which rise in the Rocky Mountains, find a way through these ranges to the Pacific Ocean. The Fraser River forces its way through a deep canon, 200 miles long, and makes a route for the Canadian Pacific; the Columbia River breaks through the Cascade Mountains at the Dalles, about three hundred miles south of the Fraser, and makes a way for the Northern Pacific and Oregon Short Line.

CANADIAN PACIFIC RAILROAD.

From Montreal this road follows the rich and fertile valley of the Ottawa 350 miles, then through a wilderness of lakes, rocks, and streams to Lake Superior, around its northern shore, past lakes and woods and over marshes, to the 94th degree of longitude, about 100 miles east of Winnipeg. A more God-forsaken country I have rarely seen—the land too rocky, thickly wooded, and wet for cultivation, the trees too low and stunted for timber. Mines are supposed to exist, but are not yet worked to any considerable extent. This was the most expensive section of the road, the outlay being some $12,000,000 for 200 miles, and a single mile of the heavy cuttings and tunnels cost as much as $750,000.

The company expended $2,100,000 for explosives, most of which were used on this section. From the 95th degree of longitude, through Winnipeg to Calgary

at the foot of the Rockies, it runs across the great plains nearly one thousand miles. The plains are generally rich, and, when irrigated, yield good crops. The rainfall, light at Winnipeg, decreases toward the mountains. The country north of the railroad, on the north branch of the Saskatchewan, is richer, has a greater rainfall, and bears heavier crops. It was on the line of this branch that the first surveys were made, and, under Mount Hooker, the highest of the Rocky Mountains, a pass was found only 3,760 feet high, and a route little longer than the one finally adopted; but beyond this pass the country was so rough and the mountain ridges so numerous that another route was found after the expenditure of over $3,000,000 in the survey of twelve thousand miles of different routes. The ascent from Winnipeg, 700 feet high, is gradual to Calgary, 2,900 feet above the sea level, thence to the summit at Stephen, 5,296 feet, 150 miles from Calgary. Thence the route descends to the crossing of the Columbia River, where, instead of following the great bend, some 200 or 300 miles, it climbs the Selkirk Mountains to the Glacier Hotel, 4,300 feet high. The glaciers come down the mountains close to the hotel, and are easily reached by a short walk.

Here are most beautiful views of glaciers, woods, and mountain peaks, affording varied and delightful excursions to the tourist. Between the first and second crossing of the Columbia River, 80 miles, the road ascends 1,788 feet and descends 2,761 feet. The gold range is then crossed at a low grade, when the road strikes the Fraser River, about 100 miles west of the Columbia, and follows its course through the Cascade Mountains, in deep canons for a long time considered impassable.

After leaving the river, the road runs across the low lands to Vancouver on the sound. This is the shortest line from the 95th degree of longitude to the Pacific Ocean, with the lowest grade and the greatest length on the plains. It is claimed to be the only line that runs from ocean to ocean, and is connected with Japan and China by its line of steamers. The Canadian Pacific Railroad Company received from the Dominion government grants of money and land far exceeding those paid to any of our railroads, and has recently obtained a subsidy for carrying the mails across the continent.

THE NORTHERN PACIFIC RAILROAD.

The Northern Pacific Railroad starts from St. Paul on the Mississippi and from Duluth on Lake Superior, 600 feet above tide water. It runs nearly due west from Duluth, 1,000 miles to Livingstone, at the foot of the Rocky Mountains. The country, after leaving Lake Superior, is rough, rocky, and is of little value except for timber, for 150 miles. There the great plains begin, and the land is fertile, producing abundant crops if well watered, for about 600 miles, when the Bad Lands are reached, about 200 miles west of the Missouri River.

The other transcontinental railroads, in crossing the plains, have a regular ascent, following the valleys of rivers, but the Northern Pacific crosses the Mississippi, Red, James, Missouri, and Little Missouri Rivers, and the divides between these rivers, at right angles. While there is a general up grade, the ascent is not as regular as on the other lines. West of the Little Missouri the up grade continues over the Bad Lands to the valley of the Yellowstone. The road follows that valley for 330 miles, to Livingstone, at the foot of the Rockies. The line passes within a few miles of the Big Horn, and there, where eleven years ago General Custer with his entire command was massacred by the Indians, now the peaceful settlers herd their cattle, and cultivate the fields of wheat and grain. At Livingstone the Yellowstone turns south, opening a way into the mountains.

A branch of the road runs to the Yellowstone Park, about fifty miles distant, and the traveler is well repaid for the whole journey if he can spend a week in the park. The main line, on leaving Livingstone, crosses the first range of the Rocky Mountains at Bozeman summit, 5,570 feet in height. The road then descends to the valley of the Missouri, and follows down the river, fifty miles, toward Helena, and passes through that mining center, brilliantly lighted with electric lights, to Mullen Pass, where it crosses the great divide at a height of 5,547 feet, 1,200 miles west of St. Paul, thence, with a general descent, following the waters of Clarke's Forks through Montana and Idaho. Montana, the watershed between the two oceans, has an elevation of about 4,000 feet above the sea level. The winters are very cold, the summers hot and dry. Only scanty crops can be raised, for there is little rain and few irrigating streams. The cattle range over the plains and mountains in summer, and, if properly fed and protected for two or three months, will stand the long, cold winters. When storms come, the cattle, unless protected, drift before the wind for many miles until they find shelter, and when the storm abates slowly return to their grazing grounds. The general elevation of Idaho is lower than that of Montana, and its great lakes soften the temperature, while the warm winds from the Pacific Ocean temper the winter climate. There is more rainfall and better soil. Wheat and grain grow in greater abundance. In both of these territories there are great stores of precious metals, the yearly product of Montana being about $25,000,000. The road runs around the beautiful Lake Cœur d'Alene, then for many miles down the Spokane River, with its beautiful falls, to Pasco on the Columbia River. Here the road branches, one line following the Yakima River, crossing the Cascade Mountains at a height of about 4,000 feet, thence to Seattle and Tacoma on Puget Sound. The other branch follows the Columbia River, which forces its way through the Cascade Mountains, at the Dalles and Cascades, to tide water at Portland, about 100 miles from Astoria at the mouth of the river. The route over the Cascade Mountains, reaching the fine harbors of the sound, will eventually be the main route. The Northern Pacific is comparatively free from the great alkali deserts found on the more southerly roads, and is therefore more comfortable for the traveler. Few more beautiful trips can be found than over this road by the Yellowstone Park to Tacoma, and thence by the Oregon and California road to San Francisco, and home by the Yosemite and the Atchison, Topeka & Santa Fe Railroad.

UNION AND CENTRAL PACIFIC RAILROADS.

The Union Pacific Railroad, with its Kansas branches, the Chicago, Burlington & Quincy and the Atchison, Topeka & Santa Fe, cross the great plains from the Missouri River to the foot hills of the Rocky Mountains, over a country very similar to that crossed by the Canadian Pacific, but with steeper grades. The Union Pacific begins at Omaha, runs thence 500 miles to Cheyenne on an up grade averaging ten feet to the mile, increasing in steepness as it approaches the foot hills; then it rises more rapidly, reaching the summit at Sherman, 8,240 feet above the sea level, 550 miles from Omaha. From thence to the top of the Wasatch Range it runs on an elevated plateau, nowhere less than one mile and a quarter above the sea level. It then descends rapidly 3,800 feet to Salt Lake, follows the Humboldt Mountain, and crosses the Humboldt Valley, over 300 miles, until the river sinks into the desert, then rising rapidly to the summit of the Sierra Nevadas, 7,000 feet, passing by Tahoe, the most beautiful of lakes, then down a grade, which when it was built was the longest and most rapid descent in the world, to tide water near Sacramento. On turning round a promontory called Cape Horn, near the top of the Sierras, the traveler looks down a perpendicular descent of 2,000 feet into the valley of the American River—one of the most beautiful views in the mountains.

The Union and Central roads were the first transcontinental railroads built. The construction was carried on during the civil war, and was finished only four years after its close. The grades are much heavier than those of either of the other roads, and it runs for a longer distance through the mountains. The grades are so unfavorable, compared with other lines, that the Union Pacific has sought another outlet by the way of the Oregon Short Line to the Pacific, and the Central Pacific has found an easier route to the Atlantic by its Southern Pacific Railroad. The Oregon Short Line, a road built and leased by the Union Pacific, leaves the main road at Granger, 875 miles from Ogden, crosses the Rocky Mountains at an elevation of 6,279 feet, to the Snake River at American Falls, 1,100 miles from Ogden, and follows the valley of this river to the Columbia, at Walla Walla junction. The valley of the Snake River is fertile. It produces fine crops with little, and in many places without any, irrigation, not on account of a greater rainfall, but from the different character of the soil. The grandest scenery in the mountains is found on the Denver & Rio Grande Western Railroad. This road starts from Ogden, the junction of the Union Central Pacific Railroad, traversing the valley of Salt Lake and its River Jordan, crossing the many ranges of the Rockies by passes over two miles above the sea level, through deep canons so steep and narrow that in the Royal George Canon the road is carried along the river on a bridge, no way being found for the road on the mountain side. At the eastern terminus the Denver and Rio Grande road connects with the Atchison and Topeka at Pueblo, and with the Union Pacific at Denver.

ATCHISON, TOPEKA AND SANTA FE.

Kansas City has heretofore been the starting point of this line, but it is now being rapidly extended east to Chicago, and will soon run a through train from Chicago to the Pacific Ocean. From the eastern boundary of Kansas it follows the line of the Arkansas River 600 miles west to La Junta, 4,000 feet above the level of the sea. Here it turns and runs to the southwest, 330 miles, to Albuquerque, thence turns and runs due west to the Pacific Ocean. It crosses two ranges of the Rocky Mountains, the first at Rincon, on the boundary line between Colorado and New Mexico, the highest pass on the road, 7,600 feet; the second at the continental divide, 1,000 miles from Kansas City, 7,200 feet high; thence along a high plateau nowhere less than one mile in elevation, 700 miles, following the Little Colorado River; thence it descends rapidly 125 miles, to the Needles, where it crosses the Colorado River at the boundary line between Arizona and Southern California, 477 feet above tide water. Then the Sierra and Coast ranges are crossed at a height of about 3,000 feet, and tide water is reached at Los Angeles, San Diego, and San Francisco. Near Albuquerque, 900 miles west of Kansas City, is a branch of the road to Santa Fe, the old city of the plains, famous for its Mexican remains. Here, too, are the hot springs of Las Vegas, having a winter climate unequaled for health. The air is dry and bracing, and more temperate than that of the far famed Colorado Springs. Holbrook, 1,100 miles from Kansas City, is sixty miles from the renowned Pueblos of the Moquis tribe of Indians.

The Plateau Country, so called, through which the Colorado River and its branches run, is reached either from Peach Springs, 1,400 miles from Kansas City, by a stage road, only 16 miles, to the Grand Canon, or from Flagg Staff, 60 miles from Point Sublime. Here is the sublimest scenery on the continent, as yet but little visited for want of easy means of access. The more it is known, the greater will be the number of visitors. The Plateau Country is the land of canons, all of which lead down to one great trunk channel cleft through the heart of the Plateau Country, 800 miles long, and with a depth of from 2,000 to 6,000 feet. Of the many canons in the plateau, the Grand Canon is the "most magnificent as well as the grandest geological section of which we have any knowledge." It is 218 miles long, from 4,500 to 6,000 feet deep, averaging 5,000 feet. Its width from crest line to crest line is from 4½ to 12½ miles, the widest portion being always the grandest. Not far from the Grand Canon, near Peach Springs, is Little Zion Valley, a canon running into the Grand Canon. "In its proportions it is almost equal to the Yosemite, but in its nobility and variety of the sculptured scenery and wonderful variety of colors, there is no comparison.

SOUTHERN PACIFIC RAILROAD.

It is hardly possible to realize how recently the territory through which this road runs came into our possession. California in 1846 was an "outlying and neglected Mexican province." New Mexico, Arizona, and southern Colorado were purchased of Mexico in 1853, under the Gadsden treaty, for $10,000,000, "because the low level of the mountains below the Gila was the natural route for a southern transcontinental railway." Soon after the purchase, schemes were formed in the East for constructing a Southern Pacific road. Fifteen years ago a few hundred miles of road were built in Texas, and the promoters applied to Congress for a subsidy. Then the managers of the Central Pacific, who controlled all the business of the Pacific slope, determined to construct the Southern Pacific without a subsidy, and thereby retain their monopoly. The road was commenced in the year 1875, and was completed in 1881. The eastern termini of this road are at New Orleans and Galveston. Like the Canadian Pacific, it crosses the continent from ocean to ocean. It passes through the rich lowlands of Louisiana and Texas, reaching the great plains a little west of San Antonio. Near this city it meets the Rio Grande River, follows its valley, ascending by a steady grade to El Paso, 1,200 miles from New Orleans; thence through New Mexico and Arizona on an elevated plateau about 4,000 feet high for 200 miles, by the foot hills and over the spurs of the Rocky Mountains, to the continental divide at Dragoon Summit, 4,614 feet above tide water; thence over the valley of the Gila and its branches to the Colorado River, which it crosses at Yuma near the mouth of the Gila, through a dry and arid desert rich in mines of silver, copper, and lead—a country long desolated by the Arapahoes; thence down into the great desert of California, 260 feet below the level of the sea, and over a low range or spur of the Sierras to tide water at Los Angeles and San Diego (the country near Los Angeles is the garden of California, where the orange tree buds, blossoms, and ripens its fruit all the year round); then over the main range of the Sierras at Tehachapi, 4,026 feet high, and down into the valley of the San Joaquin and Sacramento Rivers to San Francisco. The grade of the road is lower and more favorable than that of either of the other transcontinental roads. It is a favorite route for passenger travel in the winter and spring. In the summer the heat is so intense and the dust so thick as to render it uncomfortable.

The great plains begin at San Antonio, and run about 700 miles to the foot of the mountains near El Paso. They are much lower than in Colorado, Utah, and Wyoming, but are more arid. Occasionally on the plains west of San Antonio there has been no rainfall for one and even two years. These plains would make the finest pastures for cattle when there is sufficient rain, as the snows are light, the winters warm, and the pastures good the year through. This road and the Atchison, Topeka & Santa Fe are the only roads without snow sheds.

The Union and Central roads, when built, relied almost entirely upon the through business, now mainly upon local business, as the through business has become of comparatively little importance, because it is divided among five lines. The increase in the number of roads and the large reduction of rates have stimulated emigration, and thus the business, both through and local, is steadily and rapidly increasing. Each road now does as much business as the Union and Central when they monopolized the whole. The construction of competing roads has resulted in great benefit to the public, and, when the local business is built up, the revenues and profits of the several roads must be very large.

Other roads are also seeking new routes across the mountains. The St. Paul, Minneapolis & Manitoba has constructed several hundred miles in Dakota, and is constructing its road at the rate of five miles a day, through Manitoba and up the Missouri River to Fort Benton. It is also reported that parties in the interest of this line have commenced the construction of a line from Seattle, across the Cascade Mountains, down the Yakima River, to the Moxee Valley, and thence across to the great bend of the Columbia. The Chicago & Northwestern has already crossed the great plains in Nebraska and Wyoming, to the foot hills of the Rocky Mountains, 1,000 miles west of Chicago, and will ultimately be forced to seek a route over the Rocky Mountains, along the northern fork of the Platte River.

COMPARATIVE STATEMENT.

It will be interesting to compare the elevation and length of the different transcontinental railroads. The greatest average elevation of the mountain system of North America is in southern Wyoming and the western part of Colorado. It therefore follows that the passes over the mountains should be the highest in this section.

The highest railroad passes are:

Kicking Horse Pass, on Canadian Pacific	5,596	feet.
Bozeman Pass, Montana, on Northern Pacific	5,570	"
Sherman Pass, Wyoming, on Union Pacific	8,235	"
Pass on Denver and South Park Railroad, Union Pacific	11,250	"
Marshall Pass, Colorado, on Denver and Rio Grande, about	12,000	"
State Line, Colorado, on Atchison, Topeka & Santa Fe	7,622	"
Dragoon Summits, on Southern Pacific	4,614	"

The length of the several roads, the width of the great plains and mountains, are controlled by the configuration of the continent. The Rocky Mountains run in a southeasterly direction, while the trend of the coast is southerly, even a little southwesterly, to San Francisco, and then southeasterly to the Isthmus of Panama. This causes a diminution in the width of the great plains on the line of the Union and Central Pacific roads, and a corresponding increase in the width of the mountain systems and in the length of the road. On the Canadian Pacific the great plains are 1,000 miles wide, and the mountains about 500 miles wide. On the Union Pacific the plains are 500 miles in width, the mountains 1,300 miles.

The distances on the several roads from a common degree of longitude, say the 97th, to the Pacific Ocean, is shown in the following table:

Canadian Pacific to Vancouver	1,480	miles.
Northern Pacific to Portland	1,620	"
Union Pacific and Oregon Short Line to Portland	1,724	"
Union and Central Pacific to San Francisco	1,885	"
Atchison, Topeka & Santa Fe to San Diego	1,694	"
Southern Pacific to San Francisco	2,024	"
Southern Pacific to San Diego	1,610	"

All these roads require a harbor at the terminus on the Pacific coast. North of the lower end of Puget Sound the coast is studded with islands and excellent harbors. From Puget Sound south the mountains rise almost directly from the ocean, there are few

islands, and the only harbors are at the mouths of the rivers, and these are generally barred.

The Canadian Pacific finds a harbor at Vancouver on Puget Sound; the Northern Pacific was forced to cross the Cascade Mountains to reach a good harbor at Seattle and Tacoma on the sound; the Oregon Short Line has its terminus at Portland, 100 miles from the mouth of the Columbia River, where there is a bar which cannot be crossed in stormy weather; the Central and Southern Pacific have good harbors at San Francisco and San Diego; the Atchison, Topeka & Santa Fe at San Diego.

GARDINER G. HUBBARD.

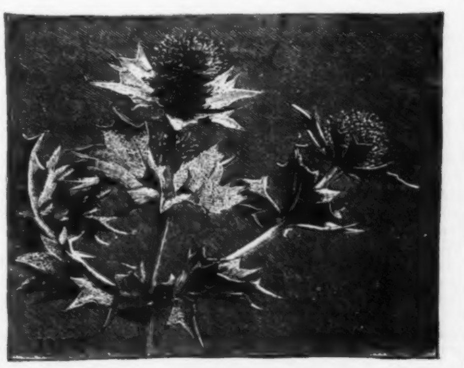
SEA HOLLIES.

(ERYNGIUM.)

THIS is a genus belonging to the Umbellifers, but so unlike that class of plants in general appearance as to be often mistaken for thistles and such like, which, indeed, they very much resemble. For general garden purposes, whether the decoration of the rockery, the border, or the lawn, few such ornamental genera yield a greater variety in the shape and length of leaves or

THE IVORY-LEAFED SEA HOLLY (E. EBURNEUM).

size and brilliancy of involucres and stems. The latter in many cases are so singularly beautiful with their vivid steel-blue tints, surmounted with an involucre even more brilliant, that the striking effect of good large groups is hardly excelled by any plants that stand the rigors of our climate so well. Some few, and notably the gigantic sea holly (E. giganteum), show very little blue unless under the involucres, and can only be described as of a light glaucous gray color. The great diversity in the cutting of the leaves is very interesting, ranging from the great Pandanus-like foliage of E. pandanifolium to the very small Thistle-like leaves of E. dichotomum. Those belonging to the Pandanus set, such as E. Lasseauxi, eburneum (see illustration), bromeliæfolium, and others, are useful in sub-tropical arrangements; their leaves being mostly of a thick, succulent, or leathery nature, are not liable to be damaged by the cold nights in early autumn; indeed, in all but very damp places or heavy soils they continue effective as regards foliage all through the winter season. E. alpinum, Olivierianum, giganteum, etc., are very useful for furnishing the mixed border or rockery, and all are enhanced for this purpose by the length of time they continue in bloom, and in the latter set especially by the long time they retain their handsome blue tints. A good, rich, but well drained soil suits most of the species. The latter especially should be most attended to, as damp carries off more of the



THE COMMON SEA HOLLY (E. MARITIMUM).

tender species during winter than cold. We find that coddling is a great mistake; they will stand any amount of exposure so long as the drainage is perfect. In localities where the rainfall is great, a square of glass over the crown is very useful. E. alpinum may be made an exception to the above directions, as we find, in the south of England at any rate, that it prefers a shady spot in a good stiff soil, and much the same treatment will also answer in the case of E. Olivierianum. The only really safe way to increase these sea hollies is by means of seed. Some few sorts may be increased by division or root cuttings, but we find they take such a long time to recover that a healthy, vigorous batch may be raised from the seed in about the same time. We sow the seed in pans as soon as gathered, and place the latter in a cold frame. The seeds germinate in spring, and if properly managed are ready to plant out the following year.

The undermentioned are a few of the most suitable for ornamental purposes:

THE ALPINE SEA HOLLY (E. alpinum).—This (see illustration) is found in the Alpine pastures of Switzerland, Piedmont, etc., and, when well grown, is certainly not surpassed in beauty by any plant in the genus. In addition to this, we find it does well in shady borders, developing a tint almost equal to that when the plant is fully exposed to sunshine. The lower leaves are produced on long petioles, deeply cordate at the base and toothed. Those on the stem are palmately lobed and serrated. Involucre bracts, ten to twelve, rather soft to the touch, a little longer than the flower heads, and with numerous spines on their margins. The involucres, as well as the stems, are of a beautiful blue, making a handsome group. Its flower stems, averaging about two feet high, are produced during July and August. There is said to be a white variety, which we have not yet seen.

THE AMETHYST SEA HOLLY (E. amethystinum).—The plant here figured has been unaccountably confounded with the much more robust E. Olivierianum, although they have little in common. The former rarely exceeds one foot to one and a half feet in height, is of a somewhat straggly habit, and has flower heads and stems of the finest amethyst blue. The lower leaves are pinnatifid, the divisions being again cut and spiny. Stems smooth, branched at the apex, carrying

THE ALPINE SEA HOLLY (E. ALPINUM).

numerous flower heads. The seven to eight involucre leaves are lance shaped, much exceeding the flowe heads in length, and with a few spines at the base only. Apart from the great beauty of its flower heads and stems, this plant is chiefly welcome on account of its pretty dwarf habit. It answers well for a first or second row in the border, and makes on the rockery one of the most charming little groups that could be desired. It can be increased by division, but is so easily raised from seed that disturbing the established plants is hardly desirable. It flowers during July and August, and is a native of Dalmatia, Croatia, etc.

THE GIANT SEA HOLLY (E. giganteum).—The plant here figured is deservedly appreciated on account of its amenity to almost all positions and varieties of soil. The large flower heads are also greatly appreciated for winter decoration, and although not highly colored like many of the others, they make pretty bouquets arranged with grasses, etc. It is an excellent plant for grouping, and in large masses, as we have frequently seen it, it forms a very picturesque object. It grows from three feet to four feet in height, with stout stems and numerous deeply lobed, spiny glaucous leaves. The involucre, of eight to nine large, oval, spiny leaves, pale gray or glaucous, is very effective. A native of the Caucasian Alps, Armenia, Siberia, etc.

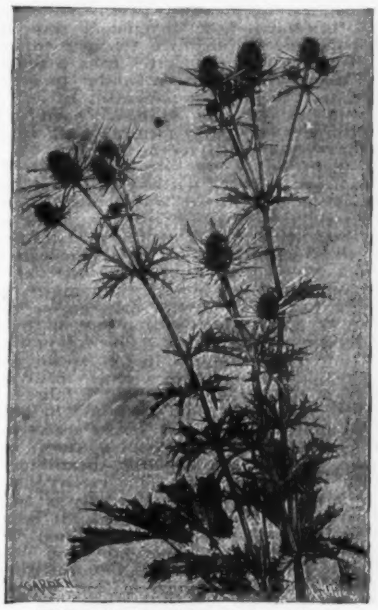
THE COMMON SEA HOLLY (E. maritimum).—This plant (see illustration) is still found growing along the coast in company with the oyster plant (Mertensia maritima). It, however, requires no special culture, and does well on a rockery in a stiff, loamy soil. It is one of the most glaucous of the species. Flowers July to October, growing from 6 inches to 1½ feet.

OLIVIER'S SEA HOLLY (E. Olivierianum).—This variety can be highly recommended. It is of easy cultivation, and the abundance of its highly colored flower heads renders it very attractive in the flower border. It has often been, and is even yet, confounded with the amethyst sea holly. E. Olivierianum grows 2 feet to 3 feet, and often 4 feet in height, with the lower leaves on long stalks often three parted, roundish in outline, and with a cordate base. The stem leaves are also three lobed and deeply lobed. The ten to twelve bracts composing the involucre are longer than the head of flowers, and have about half a dozen teeth on each side. In habit and general appearance it is more nearly allied to E. alpinum than any of the others. It, however, appears to be constant to the above characters even under good cultivation. It ripens seed freely, and in this way it may be readily increased. Native of the Levant.

Others equally attractive and desirable are E. Bourgati, campestre, cæruleum, planum, of which there is a very beautiful variety, dichotomum, triquetrum, creticum, glaciale, spina-alba, etc.

THE PANDANUS GROUP.

To this group, chiefly natives of Mexico, Brazil, etc., belong some of the most curious and extraordinary, as



THE AMETHYST SEA HOLLY (E. AMETHYSTINUM).

well as some of the most useful, forms in this highly ornamental genus. Beginning with serra, we have a large, broad leaved species with curious double spines; Carrierei, said to be the finest of all, a compact habit combined with large, beautiful leaves. E. bromeliæfolium is a charming plant, striking and distinct in habit, and forming elegant yucca-like tufts, with its graceful leaves surmounted with whitish flower heads. It stands fully exposed. E. pandanifolium is a noble habited plant, very effective when grown as an isolated plant on a lawn, etc. E. Lasseauxi is nearly allied, and perfectly hardy in the open air. E. eburneum, aquaticum, virginianum, Leavenworthi, and others, are all worthy attention for subtropical purposes.—*K., in the Garden.*

THE GIANT SEA HOLLY (ERYNGIUM GIGANTEUM).

GEMS AND ORNAMENTAL STONES OF THE UNITED STATES.

A RECENT Saturday evening lecture in the workingmen's course was delivered by Prof. A. E. Foote, of Philadelphia, in the Trophy Hall of the American Exhibition, London, on the above subject, to the largest audience that has assembled during the season. The speaker was introduced with some very complimentary remarks by Mr. F. W. Rudler, Curator of the Museum of Practical Geology, of Jermyn Street, and President of the Geologists' Association. One

reason why so little is known about American gems and ornamental stones in Europe is that there is a ready market in America for everything of the gem character that is produced there. Thus far mining for gems has been of a very desultory character, being principally carried on in connection with mica and other mines, or by farmers and others when they have but little else to do. The emerald and hiddenite mines of North Carolina and the tourmaline mines of Maine are the only ones that have been worked systematically. Gems are the purest forms of minerals, and in nearly all cases are the result of crystalline action. If the conditions of crystallization are perfect, all impurities are excluded. Ruskin, in his "Ethics of the Dust," gives a charming illustration of this by supposing the power of crystallization to be exerted upon the mud of a path of a manufacturing town. The gems peculiar to America are chlorastrolite, zonochlorite, and hiddenite. Chlorastrolite, or green star stone, is a species which was discovered by Prof. J. D. Whitney, of the United States Geological Survey, about forty years ago. The only place in the world where it is found is Isle Royale, Lake Superior. This island, belonging to the State of Michigan, forty miles long, five miles wide, and about twenty miles from the mainland, is composed of amygdaloid trap, in the almond shaped cavities of which the gem principally occurs. This green stone radiates from a center and shows a beautiful chatoyance similar to cat's eye, crocidilite, and other fibrous minerals. In 1868, when instructor in chemistry, etc., in the University of Michigan, Prof. Foote led a party from the University that camped for several months on the island.

For the first time the chlorastrolite was found in a vein stone associated with native copper and epidote. The best specimen ever found was secured by our party, and is now in Mr. Foote's possession. The second best one belongs to Mr. Morrison, of London, and the next best one, so far as the speaker knows, belongs to an American lady resident of London. About £300 worth are sold annually. Zonochlorite is a green banded stone similar to chlorastrolite in composition, but discovered by Prof. Foote at Nespigon Bay, on the north shore of Lake Superior. The full description was published in the "Transactions of the American Association for the Advancement of Science," in 1872. It is an entirely novel stone, hardness about 7, takes a very high polish, and if it could be found in sufficient quantities would undoubtedly be extensively used. Hiddenite is a green variety of the well known species spodumene. A yellow variety from Brazil has been cut as a gem for many years. This variety has been known for about seven years, and is fully as beautiful and valued as highly as the diamond. It occurs in connection with emeralds in North Carolina. The locality is worked by a stock company, and produces about £500 worth of hiddenite and £600 worth of emeralds annually. One of the finest of these emeralds is in the British Museum. The fullest series of them is in the collection of C. S. Bement, of Philadelphia. One weighs 8¾ oz., within a quarter of an ounce of the most celebrated emerald in England. Of gold quartz about £28,000 is sold annually. Most of this comes from California, where it is not only used as a gem, but in the manufacture of various ornaments. One of these, an imitation of the cathedral Notre Dame, is valued at £4,000. Prof. Foote saw no specimens in Hungary so good, though the gold penetrating amethystine quartz is very beautiful. Though Californian gold is worth about £3 10s. an ounce, nice specimens of quartz readily bring from £5 to £7 an ounce.

Although the flexible sandstone, the gangue of the diamond in Brazil, is found in mountain masses in North Carolina and other States, no very large diamonds have as yet been discovered. Many small ones are recorded from California, North Carolina, Virginia, and elsewhere. The largest was found at Manchester, near Richmond, Virginia, weighed 23¾ carats in the rough and 11$\frac{11}{16}$ carats cut. It was valued, when found, at £300, and £1,400 was loaned upon it later. Prof. Whitney states that the largest found in California was 7¼ carats. Rubies and sapphires have been found in the rock in the corundum mines of North Carolina, and C. S. Bement has an uncut green one in his collection that would give 80 to 100 carats worth of good stones, one of which would probably weigh 20 carats. This specimen is probably worth £200. The largest red and blue crystal weighs 312 pounds, and belongs to Amherst College. The best sapphires are found in the placer mines of Montana. Asteriated corundums are found in Pennsylvania and elsewhere.

About £2,200 of quartz or rock crystals are mined annually. The best localities are Hot Springs, Arkansas, North Carolina, New York, and Virginia. A portion of a mass that must have weighed over 40 pounds was recently received from Alaska, that cut a hand glass three inches by five. They are frequently dug up in the prehistoric mounds, and were used by the medicine men and others for foretelling future events. Amethysts are found in very fine specimens in Pennsylvania, Georgia, Texas, and the Lake Superior region. From the latter region they are very remarkably lined, some specimens showing "phantom crystals" equal to the Hungarian. Near the Yellowstone National Park and in the Chalcedony Forests of Arizona are tree trunks, some of which are one hundred feet long, turned to stone by the action of silicated waters. Some of these trees are still standing upright; others, having fallen, bridge deep chasms. The once hollow cavities of some are lined with amethyst, others with agate. The Arizona agatized or jasperized wood shows the most beautiful variety of colors of any petrified wood in the world, and about £2,500 worth is annually sold for ornamental purposes. Probably the most remarkable locality in the world for smoky quartz or cairngorm stone is Pike's Peak, Colorado. Here it is found in a graphic granite associated with Amazon stone, which also makes a very beautiful green ornamental stone. Over £1,500 worth of this is annually sold. The largest crystal found—over four feet in length—of good shape, and all suitable for cutting, was recently sold to the Marquis of Ailsa for £20. The rutilated quartz, or Cupid's arrows, is found in remarkably fine specimens in North Carolina. Perhaps the most remarkable mass is one 7 inches by 3⅛, now in the collections of the Academy of Natural Sciences of Philadelphia. The crystals of rutile are about the size of knitting needles. Some of the North Carolina rutile has been cut, furnishing brilliant gems closely resembling carbonado. The rutile geniculated till it forms a perfect circle or rosette, from Magnet Cove, Arkansas, is often mounted and worn as a charm. While opals are found at many places in the United States, they do not rival those of Queretaro, in Mexico. Here are found not only the "milky opals that gleam and shine like sullen fires in a pallid mist," but fire, noble, and almost every other variety known. Rhodonite, in specimens suitable for polishing, is found in Massachusetts and New Jersey. At the latter locality were obtained the finest crystals ever seen. The garnets from New Mexico and Arizona are superior to the Cape rubies from South Africa, and from Alaska the most beautiful crystals ever seen, in a setting of gray mica schist, have recently been obtained.

The New Mexican turquoise is mined to the value of about £700 annually. It has recently been described very fully by Prof. Clarke, Curator of the Mineralogical Department of the National Museum, and is especially interesting as being the material from which the "Chalchuhuitls," or most sacred images of the Aztecs, were made. The Indians still regard it as a lucky stone.

Labradorite, lately so popular for gems and ornamental stones, is found in many localities. The tourmalines of Maine are probably the finest in the world. Here are found the Oriental sapphire, ruby, and emerald in perfection. The Shepherd and Hamlin collections contain specimens that are unequaled elsewhere.

Topaz has recently been found at Pike's Peak, Colorado, in large quantity. Some masses weighed two pounds each, and very fine clear white stones have been cut, weighing from 125 to 193 carats. The topaz so nearly rivals the diamond in luster and brilliancy that it is difficult to distinguish one from the other.

Among ornamental stones should be mentioned a very beautiful variety of serpentine from Maryland called verd-antique, which is being largely used in the interior decorations of the Philadelphia court house. Another variety resembling jade is the green williamsite from Pennsylvania. Alabaster of various colors abounds in many localities, and marbles, some as beautiful as the Mexican onyx, are found in nearly every State. The lovely malachite and azurite, jet, and many other gems of minor importance, were referred to but briefly on account of limited time.

THE SUN'S HEAT.

By Sir WILLIAM THOMSON, LL.D., F.R.S., M.R.I., Professor of Natural Philosopby in the University of Glasgow.

WE supposed the two globes to have been at rest when they were let fall from a mutual distance equal to the diameter of the earth's orbit. Suppose, now, that instead of having been at rest, they had been moving in opposite directions with a velocity of two (more exactly 1·89) meters per second. The moment of momentum of these motions round an axis through the center of gravity of the two globes perpendicular to their lines of motion is just equal to the moment of momentum of the sun's rotation round his axis. It is an elementary and easily proved law of dynamics that no mutual action between parts of a group of bodies, or of a single body, rigid, flexible, or fluid, can alter the moment of momentum of the whole. The transverse velocity in the case we are now supposing is so small that none of the main features of the collision and of the wild oscillations following it, which we have been considering, or of the magnitude, heat, and brightness of the resulting star, will be sensibly altered; but now, instead of being rotationless, it will be revolving once round in twenty-five days, and in all respects like to our sun.

If instead of being at rest initially, or moving with the small transverse velocities we have been considering, each globe had a transverse velocity of three-quarters (or anything more than 0·71) of a kilometer per second, they would just escape collision, and would revolve in ellipses round the center of inertia in a period of one year, just grazing each other's surface every time they came to the nearest points of their orbits.

If the initial transverse velocity of each globe be less than, but not much less than, 0·71 of a kilometer per second, there will be a violent grazing collision, and two bright suns, solid globes bathed in flaming fluid, will come into existence in the course of a few hours, and will commence revolving round their common center of inertia in long elliptic orbits in a period of a little less than a year. Tidal interaction between them will diminish the eccentricities of their orbits, and if continued long enough will cause the two to revolve in circular orbits round their center of inertia with a distance between their surfaces equal to 6·44 diameters of each. Suppose now, still choosing a particular case to fix the ideas, that twenty-nine million cold solid globes, each of about the same mass as the moon, and amounting in all to a total mass equal to the sun's, are scattered as uniformly as possible on a spherical surface of radius equal to one hundred times the radius of the earth's orbit, and that they are left absolutely at rest in that position. They will all commence falling toward the center of the sphere, and will meet there in two hundred and fifty years, and every one of the twenty-nine million globes will then, in the course of half an hour, be melted, and raised to a temperature of a few hundred thousand or a million degrees Centigrade. The fluid mass thus formed will, by this prodigious heat, be exploded outward in vapor or gas all round. Its boundary will reach to a distance considerably less than one hundred times the radius of the earth's orbit on first flying out to its extreme limit. A diminishing series of out and in oscillations will follow, and the incandescent globe thus contracting and expanding alternately, in the course it may be of three or four hundred years, will settle to a radius of forty* times the radius of the earth's orbit. The average density of the gaseous nebula thus formed would be $(215 \times 40)^{-3}$, or one six hundred and thirty-six thousand millionth of the sun's mean density, or one four hundred and fifty-four thousand millionth of the density of water, or one five hundred and seventy millionth of that of common air at an ordinary temperature of 10° C. The density in its central regions, sensibly uniform through several million kilometers, is one twenty thousand millionth of that of water, or one twenty-five millionth of that of air. This exceedingly small density is nearly six times the density of the oxygen and nitrogen left in some of the receivers exhausted by Bottomley in his experimental measurements of the amount of heat emitted by pure radiation from highly heated bodies. If the substance were oxygen, or nitrogen, or other gas or mixture of gases simple or compound, of specific density equal to the specific density of our air, the central temperature would be 51,200° Cent., and the average translational velocity of the molecules 6·66 kilometers per second, being $\sqrt{\frac{3}{7}}$ of 10·2, the velocity acquired by a heavy body falling unresisted from the outer boundary (of 40 times the radius of the earth's orbit) to the center of the nebulous mass.

The gaseous nebular thus constituted would in the course of a few million years, by constantly radiating out heat, shrink to the size of our present sun, when it would have exactly the same heating and lighting efficiency. But no motion of rotation.

The moment of momentum of the whole solar system is about eighteen times that of the sun's rotation; seventeen-eighteenths being Jupiter's and one-eighteenth the sun's, the other bodies being not worth taking into account in the reckoning of moment of momentum.

Now, instead of being absolutely at rest in the beginning, let the twenty-nine million moons be given each with some small motion, making up in all an amount of moment of momentum about a certain axis equal to the moment of momentum of the solar system which we have just been considering; or considerably greater than this, to allow for effect of resisting medium. They will fall together for two hundred and fifty years, and though not meeting precisely in the center, as in the first supposed case of no primitive motion, they will, two hundred and fifty years from the beginning, be so crowded together that there will be myriads of collisions, and almost every one of the twenty-nine million globes will be melted and driven into vapor by the heat of these collisions. The vapor or gas thus generated will fly outward, and after several hundreds or thousands of years of outward and inward oscillatory motion, may settle into an oblate rotating nebula extending its equatorial radius far beyond the orbit of Neptune, and with moment of momentum equal to or exceeding the moment of momentum of the solar system. This is just the beginning postulated by Laplace for his nebular theory of the evolution of the solar system; which, founded on the natural history of the stellar universe, as observed by the elder Herschel, and completed in details by the profound dynamical judgment and imaginative genius of Laplace, seems converted by thermodynamics into a necessary truth, if we make no other uncertain assumption than that the materials at present constituting the dead matter of the solar system have existed under the laws of dead matter for a hundred million years.

Thus there may in reality be nothing more of mystery or of difficulty in the automatic progress of the solar system from cold matter diffused through space to its present manifest order and beauty, lighted and warmed by its brilliant sun, than there is in the winding up of a clock and letting it go till it stops. I need scarcely say that the beginning and the maintenance of life on the earth is absolutely and infinitely beyond the range of all sound speculation in dynamical science. The only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life.

I shall only say in conclusion: Assuming the sun's mass to be composed of materials which were far asunder before it was hot, the immediate antecedent to its incandescence must have been either two bodies with details differing only in proportions and densities from the cases we have been now considering as examples; or it must have been some number more than two—some finite number—at the most the number of atoms in the sun's present mass, a finite number (which may probably enough be something between 4×10^{57} and 140×10^{60}) as easily understood and imagined as number 4 or 140. The immediate antecedent to incandescence may have been the whole constituents in the extreme condition of subdivision—that is to say, in the condition of separate atoms; or it may have been any smaller number of groups of atoms making minute crystals or groups of crystals—snowflakes of matter, as it were; or it may have been lumps of matter like amacadamizing stone; which was actually traveling through space till it fell on the earth at Possil, in the neighborhood of Glasgow, on April 5, 1804; or like that which was found in the desert of Atacama, in South America, and is believed to have fallen there from the sky—a fragment made up of iron and stone, which looks as if it has solidified from a mixture of gravel and melted iron in a place where there was very little of heaviness; or the splendidly crystallized piece of iron, a slab cut out of the celebrated aerolite which fell at Lenarto, in Hungary; or the wonderfully shaped specimen, the Middlesburgh meteorite, having corrugations showing how its melted matter has been scoured off from the front part of its surface in its final rush through the earth's atmosphere when it was seen to fall on March 14, 1881, at 3:35 P. M.

For the theory of the sun it is indifferent which of these varieties of configurations of matter may have been the immediate antecedent of his incandescence, but I can never think of these material antecedents without remembering a question put to me thirty years ago by the late Bishop Ewing, Bishop of Argyll and the Isles: "Do you imagine that piece of matter to have been as it is from the beginning, to have been created as it is, or to have been as it is through all time till it fell on the earth?" I had told him that I believed the sun to be built up of meteoric stones, but he would not be satisfied till he knew or could imagine what kind of stones. I could not but agree with him in feeling it impossible to imagine that any one of such meteorites as those now before you has been as it is through all time, or that the materials of the sun were like this for all time before they came together and became hot. Surely this stone has an eventful history, but I shall not tax your patience by trying just now to trace it conjecturally. I shall only say that we cannot but agree with the common opinion which regards meteorites as fragments broken from larger masses, and we cannot be satisfied without trying to imagine what were the antecedents of those masses.

* The radius of a steady globular gaseous nebula of any homogeneous gas is 40 per cent. of the radius of the spherical surface from which its ingredients must fall to their actual positions in the nebula to have the same kinetic energy as the nebula has.

ON THE SIGNIFICATION OF THE POLAR GLOBULES.*

IT has long been known that the egg of some animals, after becoming mature and before undergoing its embryonic development, throws out certain bodies of globular form, which take no part in the embryonic development, but perish sooner or later. These polar globules have been found on the eggs of nearly all classes of animals, and it has been proved that they are real cells, composed of nucleus and cell body.

Several theoretical opinions have been expressed in regard to their signification. Some naturalists believe them to be only a kind of excretion of the egg. Others even think them to be of no functional importance, and perceive in them only a remnant of some ancestral process, a recapitulation of some ancient part of the phylogenetic development.

Now it is true that, in many animals, structures occur without any physiological value, but it is also known that such structures—as, for instance, the hind legs of whales—disappear more and more in the lapse of phylogenetic development. Furthermore, such rudimentary organs never disappear in all species and genera of a large group simultaneously, but in one genus or species they persist longer than in another. Thus, some whales possess certain of the bones of their hind legs lying between the muscles of the trunk, while others have preserved only one bone of the pelvis. Now the polar globules might have been regarded as insignificant and rudimentary as long as they were only known in a few groups of the animal kingdom. But as their existence is now proved in nearly all classes of animals, and as they appear in all of them in the same manner, we are compelled to assume that they possess at least some physiological significance.

Mr. Sedgwick Minot and your illustrious Balfour made a great step forward in attempting—each independently of the other—to attribute a high importance to the expulsion of the polar globules. As you know, they suggested that the egg cell was originally hermaphrodite, and that the polar globules were the male portion, which had to be thrown off. They based their idea upon the generally accepted view, according to which fecundation is the union of a specific male with a specific female substance. If this is true, then the fecundated ovum contains both these substances in equal quantities; and the observations upon the segmentation of the egg lead further to the conclusion of E. Van Beneden, that all cells of the body contain these two substances, and that they are all hermaphrodite. The throwing out of polar globules was, according to these views, the means of preventing parthenogenesis, which must have occurred if the male substance had remained in the egg. This was Balfour's opinion, and he formulated the same with all precaution, putting it forward as a supposition, which might prove true or not. He himself even pointed out the way by which a decision could be obtained. In his statement that, if his theory was true, polar globules would not be found in parthenogenetic eggs. Certainly, if polar globules represent the male substance, they cannot be thrown out in an egg that is not destined to be fertilized, and which therefore would not receive the male substance from another cell.

Now, I have tried to decide this question by observing whether parthenogenetic eggs throw out polar globules or not, and I discovered several years ago that polar globules certainly exist in parthenogenetic eggs. I have found them in the summer eggs of Daphnidæ, and later, assisted by my pupil Mr. Ishikava, of Tokio, I have also found them in the parthenogenetic eggs of Cypridæ and of Rotatoria.

Now it is impossible that these polar globules can contain the male part of the egg, and the question arises, What other significance can be attributed to them?

When I ascertained the facts which I have just described, I was not at the time aware of another fact that I am about to lay before you, and which seems to me to possess an important bearing upon the meaning of polar globules, and of sexual propagation in general. This fact is a very simple one. Parthenogenetic eggs throw out only *one* polar body, while sexual eggs throw out two of them.

The importance of this fact lies in the significance of the substance that is thrown out in the polar globules or polar cells. You know well that it is a true cell division which leads to the formation of polar globules, and that the first polar cell takes away from the egg cell one half of the nuclear substance. You are also aware that the second polar cell again takes away half of the nuclear substance remaining in the egg. Hence in sexual eggs three quarters of the nuclear substance originally contained in the egg cell are taken away by the two polar cells. In parthenogenetic eggs only one polar cell is formed, and consequently only one half of the original mass of nuclear substance is removed from the egg cell.

Now you know that nuclear substance is a very important thing. The experiences and reflections of the last ten years have led to the general conviction that nuclear substance is the part that controls the whole cell, and that the entire structure as well as the functions of the cell depend upon its minute structure. The nuclear substance is the idioplasma of the botanist Nageli. Upon the molecular structure of it the form and function of every cell in the body depend, and consequently the form and function of the whole body are determined by the nuclear matter or idioplasma of the first cell, the egg cell—parthenogenetic or fertilized.

If this theoretical view is correct, then we must be astonished that so much of this important nuclear substance is lost to the egg cell—namely, one half by the parthenogenetic ovum, and half as much again by the sexual one. What can be the cause that renders it necessary for this to happen before the egg cell is able to develop into an embryo?

I will give a short account of my ideas upon the subject.

(1) The nuclear substance or idioplasma of the first polar body must be detrimental to the further development of the egg, for it is thrown out in all kinds of eggs, parthenogenetic as well as sexual, and the embryonic development never begins before the first polar cell has been expelled. Now, if the nuclear substance truly controls the cell and compels it to take a certain shape and a certain histological structure, there must be such a substance, such an idioplasma, also in the youngest egg cell. This idioplasma causes the egg to develop a yolk possessing a certain color and structure, it causes the egg to form a shell of a certain thickness and structure. Briefly, it compels the young egg cell to attain a degree of histological differentiation which it did not previously possess. For the youngest egg cells are essentially similar in most animals, while mature egg cells are very different, and can often be very well distinguished in different species.

The specific idioplasma of the growing egg cell—I call it ovogenetic idioplasma—cannot be the same as that contained in the nucleus of the mature egg, and which controls the development of the embryo. It cannot be that idioplasma which determines the development of a certain egg cell into a duck and not into a swan. It cannot be that kind of idioplasma which I have called *germ idioplasma*, or simply *germ plasma*.

Of course there must also be germ plasma in the *young* egg cell. I believe that in the youngest germ cells there is no other idioplasma than germ plasma, and that this germ plasma changes into ovogenetic plasma, only a very small part of germ plasma remaining unaltered.

This remaining part grows with the growth of the egg, and finally attains the same volume as the ovogenetic idioplasma. Then the division of the nuclear substance takes place, and the superfluous ovogenetic substance is removed in the first polar globule, whereupon the egg cell contains only germ plasma.

This is my explanation of the removal of the *first* polar cell.

(2) In regard to the second, it is clear that an egg that contains only germ plasma should be capable of undergoing embryonic development, unless the quantity of germ plasma should prove to be too small. But this is not the case. Parthenogenetic eggs enter upon embryonic development immediately after the expulsion of the first polar globule. Sexual eggs do not thus develop, and we have to inquire into the reason for this. I believe it is because they throw out a second polar cell, which takes away one half of the germ plasma left within the egg cell. After this the quantity of germ plasma is too small for entering upon embryonic development, and therefore the egg cell remains undeveloped, unless the lost quantity of germ plasma be replaced in the process of fertilization. Embryonic development takes place immediately after the union of the germ plasma of a spermatozoon with the remaining germ plasma of the ovum. Consequent upon this the quantity of germ plasma in a fertilized egg again becomes equal to that which was present after the separation of the first polar globule, and also equal to that which enters upon embryonic development in the parthenogenetic egg.

This is perfectly simple, but a great difficulty remains. Why is it necessary that the sexual egg should throw out half of its germ plasma? Why does it not retain the whole quantity of this important substance?

You would perhaps answer, because the quantities of male and of female germ plasma, that are united by fecundation, must be equal. Indeed, the facts of heredity lead to the opinion that these two kinds of germ plasma must be equal in quantity, and we have microscopical observations recorded by Van Beneden, Carnoy, and others, which further support this conclusion. But if the quantity of germ plasma must be equal in both, why should the germ plasma of the egg increase so largely as to attain twice the volume of the germ plasma of a spermatic cell? Nature is not so wasteful as to throw away so important a substance for nothing. There must be an adequate cause why in sexual eggs the germ plasma must be halved before fecundation can take place.

I believe I can point out the reason why this is necessary, but before I do so I must beg you to first enter with me upon a few theoretical considerations on the subject of heredity.

Heredity depends upon the germ plasma, as I have said before. The minute molecular structure of the germ plasma causes the egg cell to develop into a duck or a swan, it also causes the egg to develop into a negro or into a European, into a Mr. Smith or into a Mr. Jones. In short, all qualities of the developed individual depend upon the constitution of this germ plasma. In my opinion sexual propagation implies the union of two different germ plasmas to form the single nucleus of the egg cell; and the two substances that are united in the process of fertilization I believe to be equal in size and quantity.

Now let us suppose that we lived at a time when sexual propagation had not yet existed, and that we were present at its origin. We should then observe the union of two different germ plasmas, both of the same size and quantity, but of a slightly different molecular constitution, one coming from one parent and the other coming from another. Both substances must be thoroughly homogeneous—that is to say, they must be composed of particles that are equal in their chemical, molecular, and morphological constitution.

Let us illustrate this by a diagram, in which we represent each germ plasma as a thread or a loop, which we know to be the microscopical form of germ plasma and of nuclear plasma in general. For simplicity's sake we will represent only one loop for the germ plasma of each parent. We have then two loops, the first representing the peculiarities of the germ plasma of one parent, and the second representing the peculiarities of the other parent, and we will discriminate between them by making the first green and the second red.

These two individual kinds of germ plasma unite and form together the nucleus of the fertilized egg, which develops into a new individual of the second generation. This individual will form again germ cells, and each of these germ cells will contain a germ plasma, which is not homogeneous, as before, but composed of two halves, derived respectively from the two parents. In each succeeding generation the germ plasma must attain to a more complicated constitution. It must contain twice as many different kinds of germ plasma as were contained in the germ plasma of the preceding generation.

If we follow this development of the germ plasma for a few generations, we shall find that union will take place by sexual propagation between the germ plasmas of two individuals of the second generation, each containing two different kinds of germ plasma. In this way the individuals of the third generation will be formed possessing germ cells which contain four different kinds of germ plasma. I have called these different kinds of germ plasma *Ahnenplasma*, a word that can be rendered in English by the term *ancestral plasma*. By sexual propagation the individuals of the third generation would give rise to individuals of the fourth generation, and the germ cells of these last individuals must contain eight different ancestral plasmas. Similarly the germ cells of the fifth generation must contain sixteen ancestral plasmas, and so on. It is thus clear that in a very small number of generations the composition of the germ plasma must become extremely complicated. By the tenth generation it would already contain 1,024 different ancestral plasmas.

We do not know how far this may go, because we do not know how small are the primary elements of germ plasma, nor do we know how many of these elements may be indispensable for the youngest and smallest germ cells. But if we imagine these elements to be excessively small, this process of doubling the number of ancestral plasmas in each generation must have come to an end after a certain number of generations, whether they were 10, 20, 100, or 1,000!

From the time at which the germ plasma first attained its utmost complexity, further sexual propagation was only possible by halving the number of ancestral plasms contained in the germ plasma. Clearly, this process of halving ought to take place in male germ cells as well as in female ones, but at this moment we are only sure of its existence in the latter. We have seen that one half of the germ-plasma contained in the nucleus of the egg cell is expelled in the second polar cell. That the nuclear substance thus expelled is true germ plasma is not a mere supposition, but a certainty. We know of developing eggs which are either fertilized or unfertilized, and in the latter case they develop by parthenogenesis. Such are the eggs of the honey bee. We may assume that if these eggs remain unfertilized they will expel only one polar globule, but that if, on the other hand, they are penetrated by a spermatozoon, they will also expel the second globule. Thus the same idioplasma that is expelled from the fertilized egg remains, and forms half of the first segmentation nucleus in the parthenogenetic egg. It must therefore be true germ plasma.

I do not doubt that this is the true significance of the formation of a second polar globule. We can see the necessity on theoretical grounds for the removal of half the number of ancestral germ plasmas; and we *actually* find that half of the germ plasma *is* removed in every sexual egg.

If this reasoning be correct, our views on sexual propagation must undergo a total change. Fertilization is no longer an unknown impulse given to the egg cell by the entrance of a spermatozoon, but it is simply the union of the germ plasmas of two individuals. The spermatozoon is no longer the spark which kindles the powder, or the relatively small force which converts potential into actual energy, but it is merely the carrier of germ plasma of a certain individual, possessing the necessary qualities for reaching, penetrating, and fusing with the bearer of germ plasma from another individual. There are no *essential*, but merely individual differences between the nuclear substance of the spermatozoon and that of the ovum. There are no such things as male or female nuclear substances, but merely male and female cells, carriers of the immortal germ plasma. The differences are wholly individual and of merely secondary importance, and nothing corresponding to the ordinary notions implied by the terms male and female exists in germ plasma.

If this be so, then it is clear that the fact of sexual propagation demands a new explanation. We must attempt to explain the reason why Nature has insisted upon the rise and progress of sexual propagation. If we bear in mind that in sexual propagation twice as many individuals are required in order to produce any number of descendants, and if we further remember the important morphological differentiations which must take place in order to render sexual propagation possible, we are led to the conviction that sexual propagation must confer immense benefits upon organic life.

I believe that such beneficial results will be found in the fact that sexual propagation may be regarded as a source of individual variability, furnishing material for the operation of natural selection. I believe that sexual propagation has become prevalent among the higher organisms for the purpose of conserving and multiplying that individual variability which owes its first origin to the protozoon condition of such higher organisms. But it is not now my purpose to speak further upon this subject; I have already discussed it elsewhere ("Die Bedeutung der sexuellen Fortpflanzung fur die Selections-Theorie," Jena, 1886).

Whatever is to be said for the above hypotheses, the facts I have the honor of bringing before you to-day seem at least to prove that sexual propagation depends on the removal of half of the germ plasma of the egg and the replacement of it by the same quantity of germ plasma of another individual. This is now a fact which may be regarded as indisputable; and, further, the existence of true parthenogenesis is now proved beyond doubt. For we know now that an egg which expels only one polar globule enters without delay into embryonic development, inasmuch as it has retained the whole of its germ plasma.

* A paper read by Prof. August Weismann before the British Association at Manchester.

LIFE INSURANCE AND MORTALITY TABLES.

THE mortality table used in life insurance can very appropriately be termed the cornerstone upon which the whole structure must rest. If its strength be inadequate to the strain brought to bear upon it, the structure must inevitably fall. Both the "regular" and assessment companies admit this truth, and the ordinary observer, seeing the wide difference in their methods, is forced to inquire, "How can claims founded upon the same source be so widely divergent in their results?"

It has been settled beyond dispute that the table founded on the lives of 100,000 persons is amply sufficient for the purpose.

There has never yet occurred a case in the published mortality experience of the companies where this mortality has exceeded or even reached the table rate. This fact being taken as a basis, it is easy to deduce the net amount that will be required to carry insurance on one's life from year to year, irrespective of the expenses necessarily attached to the transaction of the business.

The plan of insurance practiced by the assessment companies is most closely allied to what is known as temporary or term insurance in the regular companies, or increase from year to year; the principal difference being that regular companies require the payment of the necessary premium in advance, while the assessment companies attempt to meet their losses by subsequent assessments on their membership.

In the results attained, the regular companies have always met their losses promptly, nor has any trouble ever arisen through lack of sufficient premium, yet this is the rock upon which the co-operative societies have constantly foundered in the past, and must continue to go to wreck in the future, because their managers have not sufficient courage to keep their members up to the mark, through fear of a stampede.

The following tables will serve best to illustrate the point we wish to impress upon those who believe the co-operative scheme can somehow be made to succeed in the end despite the failures already alluded to. The mortality table is the one based on American experience, and the one generally used, though there is but a trifling deviation in any of them. It must be borne in mind, also, that the larger the number of lives insured, the better will be the average, and the more nearly will it approach the result given by the table.

—Table of Mortality based on American Experience—				Amt. that will insure $1,000 for one year at each age from 10 to 95.
Age.	No. Living.	No. Dying.	Expectation of Life.	
10	100,000	749	48.72	$7.48
11	99,251	746	48.08	7.51
12	98,505	743	47.44	7.73
13	97,762	740	46.82	7.57
14	97,022	737	46.16	7.60
15	96,285	735	45.50	7.63
16	95,550	732	44.85	7.66
17	94,818	729	44.19	7.69
18	94,089	727	43.53	7.72
19	93,362	725	42.87	7.76
20	92,637	723	42.20	7.81
21	91,914	722	41.53	7.86
22	91,192	721	40.85	7.91
23	90,471	720	40.17	7.95
24	89,751	719	39.49	8.02
25	89,032	718	38.81	8.07
26	88,314	718	38.11	8.13
27	87,596	718	37.43	8.19
28	86,878	718	36.73	8.27
29	86,160	719	36.03	8.34
30	85,441	720	35.33	8.42
31	84,721	721	34.62	8.51
32	84,000	723	33.92	8.61
33	83,277	726	33.21	8.71
34	82,551	729	32.50	8.83
35	81,822	732	31.78	8.95
36	81,090	737	31.07	9.09
37	80,353	742	30.35	9.24
38	79,611	749	29.62	9.40
39	78,862	756	28.90	9.58
40	78,106	765	28.18	9.79
41	77,341	774	27.45	10.01
42	76,567	785	26.72	10.25
43	75,782	797	25.99	10.52
44	74,985	812	25.27	10.83
45	74,173	828	24.54	11.16
46	73,345	848	23.80	11.55
47	72,497	870	23.08	11.99
48	71,627	896	22.36	12.51
49	70,731	927	21.63	13.10
50	69,804	962	21.91	13.77
51	68,842	1,001	20.20	14.53
52	67,841	1,044	19.49	15.39
53	66,797	1,091	18.79	16.33
54	65,706	1,143	18.69	17.40
55	63,563	1,199	17.40	18.57
56	63,364	1,260	16.72	19.89
57	62,104	1,325	16.05	21.34
58	60,779	1,394	15.39	22.93
59	59,385	1,468	14.74	24.72
60	57,717	1,546	14.09	26.69
61	56,371	1,628	13.47	28.87
62	54.743	1,713	12.86	31.29
63	53,030	1,800	12.26	33.94
64	51,230	1,889	11.68	36.87
65	49,341	1,980	11.10	40.13
66	47,361	2,070	10.54	43.70
67	45,291	2,158	10.00	47.64
68	43,133	2,243	9.48	52.00
69	40,890	2,321	8 89	56.75
70	38,569	2,391	8.48	61.98
71	36,178	2,448	8.00	67.66
72	33,740	2,487	7.54	73.73
73	31,243	2,505	7.10	90.17
74	28,738	2.501	6.68	87.03
75	26,237	2,476	6.28	94.37
76	23,761	2,431	5.88	102.31
77	21,330	2,369	5.48	111.06
78	18,961	2,291	5.10	120.82
79	16,670	2,196	4.74	131.73
80	14,474	2,091	4.38	144.46
81	12,383	1,964	4.04	158.60
82	10,419	1,816	3.71	147.30
83	8,603	1,648	3 30	191.56
84	6,955	1,470	3 08	211.36
85	5,485	1,292	2.77	235.55
86	4,193	1,114	2.47	265.68
87	3,079	933	2.19	303.02
88	2,146	744	1.93	346.69
89	1,402	555	1.69	395.86
90	847	385	1.42	454.54
91	462	246	1.19	532.47
92	216	137	.98	634.26
93	79	58	.80	734.18
94	21	18	.64	857.14
95	3	3	.50	1,000.00

This table shows conclusively the net cost of insurance, and to which must be added a fair percentage for expenses. It is evident then that no company, either regular or co-operative, could furnish genuine insurance for less money for any considerable number of years. Again, it must not be forgotten that the benefit of selection will disappear after about five years, so that the early history of any company should show a death rate considerably lower than that of the table. This fact will account for the light assessments required during the first few years, but which speedily become heavier until they reach a normal standard as the societies grow older.

The list of assessment societies is far too long to be given entire, but the following table of some of the most prominent of them, where the income was over $200,000 in 1886, will be sufficient:

Began Business.		Proportion of Assessments and Annual Dues in 1886, at Various Ages, to $1,000 Insurance.				
		Age 20.	Age 30.	Age 40.	Age 50.	Age 60.
1878	American Legion of Honor, S. C., Boston	$7.50	$7.92	$11.52	$15.84	$28.80
1883	Bloomington Mutual Life Association	7.25	8.30	10.16	13.81	18.33
1881	Bay State Benefit Asso'n, Westfield, Mass	6.25	7.93	10.52	14.72	25.15
1879	Chosen Friends, Ind'polis.	6.65	7.00	8.50	12.75	27.50
1877	Covenant Mutual Benefit Association	5.64	7.36	8.73	10.79	14.21
1879	Equitable Aid Union, Columbus	6.16	7.40	9.25	12.33	18.50
1880	Hartford Life & Annuity	5.41	6.91	9.33	12.25	22.32
1879	Massachusetts Benefit Association	7.60	8.33	10.62	15.33	27.40
1883	Mutual Benefit Life Association, N. Y.	8.00	8.50	10.20	12.40	22.60
1879	Mutual Relief Society, Rochester, N. Y.	10.00	10.90	13.15	17.65	19.00
1881	Mutual Reserve Fund Life Association	10.00	10.80	13.52	18.00	38.00
1874	Northwestern Masonic Aid Association, Chicago	5.92	6.92	8.21	12.11	14.72
1877	Royal Arcanum, S. C., Boston	4.67	6.19	8.91	13.71	16.67
1884	Western Union Mutual Life, Detroit	7.28	7.52	8.41	10.62	18.37

It will be noted from the above table that there is a considerable difference existing in the assessments made upon the membership, and that the oldest of them has been in operation but a little over ten years, while the majority have been in operation less than half that time. A comparison of the cost at the several ages with that of the mortality table will show how much margin has been left for expenses. As a large number of these societies are fraternal in character, the expense account is comparatively light and may remain so from year to year, but the cost of insurance to the membership is one that, as the table shows, must increase steadily from year to year, until it becomes a burden too heavy for the membership, who finally drop out; first the younger and healthier element, and lastly, through the consequent increased mortality, the older lives, and there being no element of cohesion, nor no evenness of premiums, the society goes to pieces in the usual way. This is the hard logic of facts time and again proved. The two systems may be compared to two business firms, the one conducted on a cash and the other on a credit system, and it is obvious that the first can afford to sell its goods cheaper than the latter, who must make good his losses at the expense of his better paying customers. This is exactly the result attained by the assessment companies, since the members left out in the cold, when the society goes to pieces, have been paying the losses of others, but have derived no good result to themselves by the transaction, and have possibly in the meantime become unable to pass an examination for admission in the regular companies which, by requiring an adequate amount at the outset, can carry out every contract on their books, down to the last surviving member.—* *, *Insurance World.*

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